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HYDROLOGY.—*Our water supply.*[1]

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GENERAL CONSIDERATIONS

Water in relation to physical processes.—In the physical and biological evolution that has taken place on the face of the earth, water has had a unique function as the principal vehicle for the transfer of matter and energy. It appears that all evolution, whether physical or biological, requires, on the one hand, sufficient rigidity to supply a degree of stability and permanence, and on the other hand, sufficient fluidity or plasticity to permit more or less gradual change in response to applied energy. In the physical evolution of the earth there have been two major complimentary processes. One has been the repeated raising of parts of the solid exterior of the earth to considerable elevations above sea level through deformation and the intrusion or extrusion of fluid or plastic rock material; the other has been the reduction and modification of the raised parts, chiefly though not exclusively, through the agency of the water acting in its role as the transporter of matter and energy. Thus the development of the geologic structure of the outer part of the earth and the creation and recreation of the land areas in all their characteristic detail, have been accomplished chiefly because the earth is surficially rigid but fundamentally plastic, and because there is a supply of water which has served as the principal agent in mechanical weathering, as the carrier of oxygen and other elements that are active in chemical weathering, and as the transporter of the weathered materials in suspension or solution with subsequent deposition of these materials and forming of the sedimentary deposits.

Although the poet may regard mountains as the symbol of eternal permanence, the geologist knows that they are ephemeral features which stand majestically for but a brief period, only to disappear under the erosive work of the water. To the geologist the work of the

[1] Address of the retiring president of the Washington Academy of Sciences delivered January 21, 1937. Received January 23, 1937.

water is almost everywhere in evidence—in the sculpture of the land, in the character of the soil and subsoil, in the vast succession of sedimentary formations with their numerous unconformities witnessing to repeated cycles of uplift and erosion, in the texture of the rocks, and even in the mineral deposits within the rocks.

Water in relation to life.—The work of water is no less evident in the evolution of the plant and animal kingdoms. The Cambrian strata contain the record of abundant marine life. In the half billion years that have elapsed since the Cambrian period both plant and animal kingdoms have undergone vast evolution, with extensive and effective adaptation for life on the land and even in the most arid regions. However, in this long process of radical adaptation to different environments no species of plant or animal has escaped from the fundamental requirement of a water supply in order to carry on its life processes. Deprived of water, all plants and animals would perish. Deprived of water, the human race, with all its thought and emotion and spiritual aspiration, would come to prompt oblivion.

When consideration is given to the narrow range of temperature and other conditions that are required to provide a utilizable supply of water to living creatures, it seems evident that relatively few heavenly bodies are adapted to support life as it is known to us. Nevertheless, in the inconceivably large multitude of heavenly bodies there may be, in the aggregate, many that have the proper conditions for a water supply and that support living creatures comparable with those that exist on this earth, or that existed in the Cambrian period, or that will exist in ages yet to come. Moreover, it seems reasonable to believe that there is a spiritual character to the universe which has a reality and means of expression that are not limited by the special physical conditions found on this earth. But, however incidental water may be in the ultimate plan of the universe, for life on our own earth its need is fundamental and inescapable.

As the plant and animal kingdoms moved in large part from the sea to the land, radical adaptations to their changed water supply resulted. Thus it became necessary for both the land plants and the land animals to adapt themselves to the use of fresh water instead of salt water, and this adaptation has become so thorough that now salt water means death to nearly all land life. Thus also was developed the constant-temperature adaptation of the warm-blooded animals, operated by means of water acting as the medium for transporting energy in the form of heat, and this has led to parental care and pro-

longed adolescence, and ultimately to the fruition of intellectual and social evolution in the human race.

Water in relation to human activities.—With advancing civilization the human race has found water to be a most convenient substance for a large and ever enlarging list of uses. Indeed, its several properties, such as its solvent properties, its high specific heat, its occurrence in the solid, liquid, and gaseous states within convenient temperature intervals and with high latent heat in passing from one state to another, lend themselves so remarkably to the needs of civilized man in his multitudinous domestic and industrial operations, recreational activities, and therapeutic applications that it seems as if these properties had been providentially designed for the benefit of man. It is an interesting exercise to make a list of the uses to which water is put by man, many of which are analogous to the physiological uses of water by living organisms, as for example, the conveyance and storage of material and energy, often with resultant chemical changes, the regulation of temperature, and the elimination of waste. It will be noted that in most of these uses, water serves as the vehicle for conveying either matter or energy. It is not surprising that water has acquired a unique religious significance as the symbol, in the rite of baptism, of spiritual cleansing and regeneration by the washing away of all sin.

The average per capita consumption of water in the cities and towns of the United States amounts to more than 100 gallons a day. Some of this water is wasted but most of it is used for beneficial purposes. In the future the volume so used will be increased and new uses will be developed. Thus, the rapid advance in air conditioning of buildings is producing an almost alarming increase in the demand upon our public water supplies. It may therefore be expected that, even with reduction in waste, the consumption of water will increase with advancing civilization. One of the truly great achievements of civilized man is that of providing, for human use, abundant, convenient, and reliable supplies of water of good quality. Indeed, the improvement of the quality of the water supplies has been a major factor in increasing the average length of human life. However, considering the less advanced countries of the world and the rural sections of our own country, it is evident that the task is still far from being completed.

The ultimate water supply.—The great residual reservoir of water is the ocean, which contains all except a small percentage of the ex-

ternal water of the earth, the rest being on the surface of the land, or in the interstices of the soil and rocks, or in the atmosphere. It is necessary to distinguish between the external and the internal water, for there is evidence that water is one of the constituents of the magma that forms the interior of the earth, and the total quantity of this internal magmatic water may be very great. The supply of external water is apparently being augmented by the extrusion of internal water and possibly by acquisition from outer space. There are also processes in operation which release water from chemical combination, but these are compensated more or less by processes which tie up some of the existing external water. Any attempt to evaluate these several processes would be quite academic. It appears that any changes which may have occurred in the total quantity of external water have not had effects of major importance within the period of definite geologic record. It also appears that no changes are in prospect that will affect appreciably the future affairs of man. Although the total quantity of external water has apparently not changed significantly, fluctuations in sea level, probably due to other causes, have been of primary importance throughout geologic history, including relatively recent time. Indeed, many of the large cities of the earth are at present situated below the levels of strands that have been washed by the sea since the human race began to live on the earth.

The hydrologic cycle.—The water that is of principal concern to man is the land water—the water in the lakes and ponds and in the brooks and rivers, the water that forms the soil moisture, the water in the rocks that supplies the springs and streams and wells. Any natural or artificial change that increases the supply of land water where it is needed, eliminates it where it is destructive, improves its quality, or increases its availability is a distinct human gain; any change in the opposite direction is human impoverishment.

The land water is not a stationary supply but forms a part of an ever-recurring circulation of great complexity and variation, which is known as the hydrologic cycle. The prime mover in this cycle is the sun, which, in the last analysis, furnishes the energy that evaporates water from the sea and conveys it as vapor to higher elevations on the land, where it is precipitated, chiefly as snow or rain, with potential energy that tends, through the force of gravity, to carry it back to the sea. The solar energy is also applied in causing evaporation from the lakes, ponds, swamps, and streams, from the land surface, from objects on the surface, from the soil, and, by transpiration, from

the leaves of growing plants, including the native and cultivated trees, shrubs, and herbs. Indeed, the records of precipitation and run-off show that only about a third of the water that falls as rain or snow in the United States reaches the sea—about one-half in the eastern part of the country, only a small percentage on the Great Plains, and virtually none in the Great Basin.

In its return course, the water flows over the land surface and through the stream channels and percolates through the interstices of the soil and the water-bearing formations. In its course it performs work of great variety, some of which is beneficial and some injurious to man, and much of which has been modified for better or worse by the intelligent or unintelligent activities of civilized man.

Thus the hydrologic cycle consists of two phases—one phase including evaporation, atmospheric movement of the water vapor, and ultimately its condensation and precipitation upon the land; the other phase including the movement and temporary storage of the precipitated water upon or under the land surface while on its way to the sea or to points of re-evaporation on the land. Both phases are very complicated.

FIRST PHASE OF THE HYDROLOGIC CYCLE

Natural fluctuations in humidity and aridity.—Let us consider the first of these two phases of the hydrologic cycle. The terms *aridity* and *humidity*, as the opposite of *aridity*, are difficult to define in precise terms. In a widely accepted sense, however, the term *aridity* relates to the deficiency of the precipitation in a given area for the normal growth of mesophytic vegetation that is otherwise adapted to the conditions of that area. In this sense the aridity of an area is intensified by decrease in the amount of precipitation and also by increase in the evaporativity of the area—that is, in the potential rate of evaporation. Both precipitation and evaporativity vary radically from place to place and from time to time, largely because of temperature variations, which are produced by a complex of different causes.

The geologic record, covering some hundreds of millions of years, seems to show that long ages of relatively warm and equable climate, perhaps with a general tendency toward aridity, were at several times interrupted by shorter periods of more variable climate including some cold, humid stages. The latest of these variable periods began, perhaps a million years ago, with the first of the Quaternary glacial stages and is apparently still in progress. The geologic record shows

that the Quaternary, and perhaps also older periods of the same sort consisted of several major glacial stages alternating with distinct interglacial stages, and that the glacial stages, or at least the last one, consisted of two or more substages involving considerable climatic fluctuations. The greater humidity of the glacial stages was in large part caused by decrease in evaporation. From biological evidence and the evidence of marine terraces, it appears that we are at present in an intermediate position, having receded only part of the way from the last glacial stage. From intensive study of geologic, archeologic, and historical records it is, however, evident that recent time has not consisted of a gradual change from glacial to inter-glacial conditions, but rather of complicated fluctuations of climate, in part regional rather than world-wide, between periods that were more humid and periods that were more arid than the present.

All about us we have impressive evidence of climatic change, such as the great sheets of glacial drift and trains of outwash gravel, the scores of desiccated or partly desiccated lakes, including the extensive Lakes Bonneville and Lahontan, and the great mantle of loess or wind-blown silt that covers much of the interior of this country and is largely responsible for its great fertility. Looking more closely at the evidence of fluctuations furnished by existing lakes, glaciers, tree rings, etc., and the available records of measured precipitation and stream flow, we stand impressed by the great and irregular climatic variations of the immediate past.

Thus at the end of the disastrous drought year of 1936, we in this country look into the future somewhat bewildered and almost afraid, the more so because we recognize that much of the productive part of our country is not very far from the margin of semiaridity. We must frankly admit that in spite of all our investigation we do not know in which direction we are trending—toward greater humidity or more severe droughts—in the ensuing year, decade, or century. We can, however, make some predictions, which are in part reassuring and in part otherwise. It is virtually certain that drought conditions are not permanent but will be followed by years of abundant rainfall and bounteous crops; on the other hand, it is almost equally certain that the recent droughts are not abnormal but that in the course of time other droughts of equal and even greater severity may be expected.

It is believed that the climatic fluctuations of the past have been the underlying cause of much turmoil in human history. But it is significant that the human race has not only managed to live through

the times of drought and the intervening cold and wet times, but also that it has had its notable evolution in this Quaternary Period of strongly fluctuating climate. The climate of the present, as the climate of the past, challenges man to greater effort and achievement.

The possible influence of artificial changes upon precipitation.—When during periods of wet years the settlers moved into the semi-arid region of our country and found to their delight that they could raise good crops, they fondly developed the faith that rainfall follows the plow. Now, after a series of years of drought and crop failure, this faith has been sorely tried, and we are tormented with the fear that on account of the acts of man in plowing and draining, our country is rapidly becoming a desert. In the presence of such intense public concern it is difficult to maintain a wholly judicial attitude. It is reasonable to expect that fluctuations in humidity such as are known to have characterized the past, should also occur, through wholly natural causes, in the present and future. This logical inference, however, does not afford any reason for assuming that the very extensive and radical changes which have been made by the white men on the face of our country have produced no effects toward greater humidity or aridity. Neither may it be assumed that such effects can be of no practical consequence if they are obscured by natural fluctuations.

If the average annual contribution to the precipitation upon a continent from water evaporated out of the sea remains the same, then the drainage of swamps should reduce the average annual precipitation because some of the swamp water that would normally be evaporated and reprecipitated is drained away into the sea. On the other hand, the diversion of water from streams that flow into the sea and the use of this water for irrigation should tend to increase the precipitation. Moreover, any changes incident to cultivating and cropping the land or to grazing the land should decrease or increase the precipitation according as they increase or decrease the run-off into the sea. It is generally believed that these artificially produced changes in run-off cannot be quantitatively competent to produce appreciable changes in precipitation. However, it is pertinent to inquire whether they may have significant effects in some critical areas. It would seem that the subject deserves serious investigation.

SECOND PHASE OF THE HYDROLOGIC CYCLE

Return flow and storage en route.—The other phase of the hydrologic cycle consists of the flow of the precipitated water toward the sea or toward places of re-evaporation from the land, and its storage en

route, chiefly as ice and snow, as surface water in the lakes, ponds, and swamps, as moisture held by molecular attraction in the soil, and as ground water in the subterranean reservoirs formed by the porous rocks. To the extent that the storage facilities are inadequate, the precipitated water is rapidly discharged into the sea through the natural drainage channels as direct run-off. This direct run-off is of little value to man and it produces most of the destructive floods and most of the destructive erosion and sedimentation. If there were no natural storage facilities there would be virtually no springs, no perennial streams, and no trees, grass, or crops, and all stream channels would be subject to sudden and violent floods.

Near the close of the last century it became evident in this country that accurate continuous records of stream flow were essential for efficient utilization of the water resources and for effective flood control. Since that time a large amount of systematic stream gaging has been done, with accuracy increasing from year to year. Intensive studies have also been made to differentiate between the direct run-off and the run-off derived from the several kinds of storage, and to determine the laws of each and their relation to precipitation. In some of the coastal regions large quantities of ground water are also discharged into the sea without appearing at the surface, such discharge being controlled by the geologic structure, the permeability of the water-bearing formations, and the balance between the head of the ground water and the back pressure of the heavier sea water.

Civilized man has made a notable achievement by supplementing the natural storage facilities with many artificial reservoirs, both great and small. Unfortunately, this achievement is likely to prove less substantial in the long run than is popularly supposed, chiefly because of the rapid accumulation of sediment brought to the reservoirs by the turbid waters of the direct run-off. Much careful study has already been given and much more is needed to determine the rates of sedimentation under different conditions and to devise feasible methods of prolonging the life of reservoirs by by-passing the most turbid waters, by sluicing out the sediments, or by other means. Much progress has recently been made in the appreciation of the great value of the natural storage facilities and the importance of conserving and utilizing them. The whole complex subject affords a large field for future study and constructive effort.

Ice and snow storage.—Ice and snow have recently come into the scientific limelight in different ways. One of these relates to the interest of geologists in the relation of the Quaternary and older glacial

stages to fluctuations of sea level and to the cyclic character of some of the stratified rocks of marine origin. Thus it is now believed that in some of the glacial stages enough water was locked up as glacial ice to depress the sea level as much as several hundred feet, and that, on the other hand, many of the ancient sea terraces, such as occur on the Atlantic and Gulf Coastal Plain, were formed during interglacial stages when there was even less ice than at present. It has been estimated that if all the ice that exists at present in the polar regions were melted it would raise the sea level at least 100 feet and perhaps 200 feet or more. The advance and retreat of existing European glaciers have long been recorded, but systematic observations on North American glaciers have only recently been undertaken. Interest in snow relates chiefly to the snow in the mountains, which supports the summer flow of many streams, and to recently developed methods of estimating the annual snowfall and predicting the resultant stream flow.

Storage of water in the soil.—A soil may be regarded as a water reservoir, its water being in the form of moisture adhering to the soil particles. This water is under complicated stresses produced by combinations of the molecular attraction of the soil, the downward pull of gravity, the absorptive energy of the plants, and the energy involved in the relation between the soil moisture and the atmospheric vapor. The slow movements of the soil moisture in response to these stresses are of much importance in plant growth and in recharge of the water-bearing formations, and they have properly been the subject of much study.

The value of a soil for producing crops depends largely on its capacity to hold its water supply against the pull of gravity and yet to yield this retained water to the roots of the plants. A clean dune sand retains so little water that even in a humid region it may support only cactus and other drought resistant plants; on the other hand, a clay soil has a large water-retaining capacity but may hold most of its water in dead storage in so far as the roots of the plants are concerned. Between these extremes are the productive soils of intermediate texture, such as the loams formed from the loess, which hold considerable water against the pull of gravity and yield it freely to the plants.

Dry farming methods consist largely in utilizing the reservoir capacity of a soil by storing in it the rain and snow water of one or more years and making it available to a crop that is grown in a much shorter period. Unfortunately, soils do not generally have the capacity

to store the quantity of water that is needed to produce a crop without replenishment by rains or irrigation at more or less frequent intervals during the growing season. In the eastern and especially the southeastern part of this country it frequently happens that the soil moisture is fully replenished early in the winter and that for many weeks thereafter water from the rain and snow percolates through the soil without adding to its water content. In the ensuing summer, however, the soil moisture may become depleted long before the crops have matured, and severe drought damage may result.

Agriculture is, from the viewpoint of this discussion, one of the greatest of all achievements of man in the utilization of our water supply, but soil erosion, like a dread disease, gnaws at its roots. The erosion of the soil removes a part of the water reservoir that it utilized in crop production, and especially the upper part, which generally has the greatest capacity for holding water available to plants. Thus the measures undertaken to check soil erosion are measures of water conservation.

Storage of water in the rock formations.—The systems of rocks that form the outer part of the solid earth are the products of all the diverse and variable geologic processes that have been operative through the ages. The description and interpretation of these rock systems, with their almost infinite complexity, is the task of the geologists. The rock systems constitute natural systems of waterworks with many reservoirs of great variety, some of which have very large capacity. The study of these natural waterworks and their operation is a task of the hydrologists. It is a task that has required the development of a distinctive technique in the application of the science of fluid mechanics and hydraulic engineering to the geologic structure of the rocks.

The porous and permeable rock formations which constitute the underground reservoirs are saturated below a certain imaginary surface that is called the ground-water table. In other words, the underground reservoirs are filled to the level of the water table. In most places the roots of the plants do not extend downward to the water table or to the capillary fringe, which occurs directly above the water table, and there is therefore an intermediate belt between the root zone, or belt of soil moisture, and the zone of saturation.

Replenishment of the underground reservoirs.—The underground reservoirs are replenished, or recharged, with water from atmospheric sources. Nearly all hydrologists believe that the recharge is essentially all from rain and snow or from streams fed by rain and snow, but there are still a few hydrologists who believe that subsurface con-

densation is a substantial source. The amount of recharge from a given amount and kind of precipitation varies with the absorptive or intake capacity of the soil or other surficial material and inversely with the capacity of the soil to hold the water for plant use instead of allowing it to percolate downward to the water table.

The intake capacity constitutes a large subject with many ramifications. It includes questions as to the effects of the vegetable mold in the forested areas and of the natural sod, and, on the other hand, the effects of grazing and of the cultivation of the soil. It includes also the problems of artificial recharge by spreading stream water or by other means, and of the silting up of the natural recharge channels by surface storage or other manipulation. The surface conditions of both forests and sod-covered prairies are favorable to intake by keeping the rain and snow water clean and thus permitting it to percolate downward through the available ducts and pores without clogging them, whereas under some conditions the cultivation of the soil tends to decrease the intake capacity, especially in heavy and prolonged rains, by puddling the top layer of soil and choking the intake openings. However, forests consume large quantities of water by transpiration, which tends to offset their large intake. The conflicting results obtained by different investigators as to the effects of forests on the water table and on the flow of springs and streams, as compared to the effects of cleared or cultivated land, are in part due to the fact that in some places and at some times the balance is actually on one side and in others on the other side. Relatively little investigation has as yet been made of transpiration on the sod-covered prairies and of the effects of breaking up and cultivating the prairie lands. It appears probable that there is a basis in fact for the prevalent belief that the advent of the white men in this country was attended by a certain amount of lowering of ground water levels and of decrease in the flow of springs and streams.

It appears that artificial recharge by water spreading, by impounding of surface water and regulation of stream flow, and perhaps by drainage into wells, has large possibilities for increasing the perennial supply of ground water in certain specific areas of heavy consumption in which the natural conditions are favorable. On the other hand, for the country as a whole, recharge by such means will remain small in comparison to the total natural recharge and the total discharge of ground water through stream flow and through evaporation and transpiration. Greater aggregate increase in recharge is likely to result from general improvements in agricultural practice and from structures designed to retard soil erosion.

Great as are the variations in precipitation from place to place and from year to year in the same place, the variations in ground-water recharge are still greater. It is now known, for example, that perennial supplies amounting to many millions of gallons a day are available to wells through natural recharge of the sand and gravel in the fill of the coastal valleys and the Great Valley of California, the glacial outwash sands and gravels of Long Island, the Rhine Valley and the plain of northern Germany, the dune sands of Holland, the creviced limestone in the Roswell artesian basin in New Mexico, the broken lava rocks of the Snake River Plain in Idaho and the Islands of Oahu and Maui, and the water-bearing rocks of various other areas. On the other hand, there are areas in which ground-water recharge is extremely small, either because the surface terrane is impermeable or because the water absorbed from scant precipitation is nearly all evaporated or utilized by plants before it reaches the bottom of the root zone. Large areas in the arid and semi-arid parts of this country have only very meager recharge because the precipitation is light and occurs largely in the growing season. Yet many of these areas are underlain by water-bearing formations that contain large stores of accumulated water which they will yield freely to wells so long as the supply lasts. In the coastal region of California and in the Great Valley the soil normally becomes desiccated during the long dry summers. In winters of subnormal precipitation the precipitated water is here largely required to restore the soil moisture, and there may be little ground-water recharge; in exceptionally wet winters, however, the water-retaining capacity of the soil is satisfied long before the end of the rainy season and very large quantities of water percolate to the water table, either locally through the soil or through the channels of the influent streams. In the relatively humid eastern part of the United States there is normally considerable recharge not only in winter and spring but also in wet periods in summer, but in the drought of 1930–31 some localities were devoid of recharge for nearly a year. In cold regions with only moderate precipitation nearly all the recharge may occur in a very short time in the spring when the snow melts and the frost leaves the soil. In such regions there are also great differences in the annual crop of ground water.

Relation of the water table to the plant kingdom.—It has already been pointed out that in most places the roots of the plants do not obtain their water supply from the zone of saturation. Throughout the greater part of the extensive and productive interior agricultural region of our country, the staple crops depend on the soil moisture

derived directly from the rain and snow and fail if that supply becomes exhausted, regardless of the quantities of water that are stored below the water table. On the other hand, however, water from the zone of saturation is utilized, either habitually or in times of drought, by native and cultivated plants in many low places, including large parts of the Atlantic and Gulf Coastal Plain, the glaciated region, and the stream valleys and structural valleys in other parts of the country. Thus the relation of the water table to forest and fruit trees, staple crops such as wheat, corn, and alfalfa, garden truck, and native grasses is a subject of great consequence.

It is estimated that in the eastern part of the United States at least one-third of the water discharged from the zone of saturation is discharged by transpiration or evaporation, the rest being discharged as stream flow. In some of the summer months the discharge by transpiration and evaporation may greatly exceed the discharge by stream flow. In going toward the less humid parts of the country the total annual supply of ground water decreases but the proportion discharged by plants increases, until in some of the arid sections virtually all the water discharged from the zone of saturation is through plants, and the phreatophyte vegetation, which taps the zone of saturation, stands in striking contrast to the other desert plants.

Probably the greatest deficiency in hydrologic knowledge, especially in this country, is in the important practical subject of the relation of the native and cultivated plants to the water table. Not enough attention has been given to the water table by botanists, silviculturists, or agronomists, and adequate information is not available on such important subjects as the phreatophytic habits of trees and their relation to forestation in the arid and semiarid regions, the depth to which different cultivated plants will extend their roots to reach the water table, the optimum depth to the water table, and the increase in crop production resulting from use by the plants of water from the zone of saturation. The intensive drainage developments that have been made in this country have been based too largely on the concept that the water table is a detrimental feature, and not enough consideration has been given to the value of the water table to plants under proper conditions. On the other hand, the inadequacy of specific information on this subject is largely responsible for exaggerated statements that are made from time to time as to the disastrous results to agriculture from general lowering of the water table.

Relation of underground storage to stream flow and to water supplies

from wells.—The principal function of a reservoir is to store water for future use. The underground reservoirs function naturally like lakes and ponds in equalizing the stream flow, but they are more effective because of the retardation of the ground water by the friction of the rock interstices. Underground reservoirs of some sort are almost universally present and are chiefly responsible for the sustained flow of streams. The ground-water run-off carried by the streams is relatively constant as compared with the very erratic uncontrolled direct run-off, but it is nevertheless sensitive to various weather conditions and is generally greatly reduced by severe drought. Streams differ greatly in the quantity and fluctuation of their ground-water run-off according to the geology and other natural conditions of the drainage basins. A subject that has received little investigation but is of much scientific and practical interest is the relation of geology to stream flow.

The underground reservoirs function like artificial reservoirs with controlled outlets only when they are tapped by wells that extend considerably below the water table. Shallow wells that merely skim off ground water from the top of the zone of saturation are likely to fail when the water table is lowered by drought, but the wells that extend deeper into the water-bearing formations and have access to their great stores of water are not appreciably affected by drought. Reports of failure of such wells are commonly due to mechanical defects in the wells or pumps, or to attempts made in times of drought to increase the rate of pumping beyond the normal capacities of the wells. By drawing water from wells in proper amounts the storage facilities of the underground reservoirs are utilized and ground-water recharge is increased.

Yield of the artesian reservoirs.—A problem of great practical significance relates to the perennial yield of the underground reservoirs. To what extent is the water that is annually being drawn from pumped or flowing wells derived from annual recharge and to what extent is it taken out of storage, with the prospect of ultimate serious depletion? From which of the water-bearing formations can additional perennial water supplies be developed and where can these developments be made? These questions are more intricate for the artesian formations, which are under confining covers, than for the water-bearing formations that have water-table conditions and hence have their wells in or near their intake areas. They are also more intricate for the extensive artesian sands and sandstones, which transmit their water through small inter-granular interstices and exhibit considerable volume elasticity, than for the artesian limestones and

lava rocks, which have much larger water conduits and are more rigid.

Among the large artesian sandstones of the United States are the Cambrian sandstones of the interior, the St. Peter sandstone, the Dakota sandstone, and the series of thick sands or sandstones of the Atlantic and Gulf Coastal Plain. In these sandstones centuries may be required for water to percolate from the intake areas to the localities of the wells. The total quantities of water that they hold in storage are indeed very large, and the quantities that they will yield from storage merely through the compression that results from the release of artesian pressure of the confined water apparently may amount to millions of gallons a day for many years. It is believed that the phenomenon of compression with decrease in artesian pressure has been demonstrated to be of primary importance in the study of the perennial yield of these artesian sandstones, but the mode of compression has not been given much investigation. Presumably compression occurs largely in the strata of relatively fine grain which feed into the strata of coarser grain that supply the wells. The phenomenon of reexpansion with increase in artesian pressure is also known to occur to a considerable extent. It is more difficult to explain than the compression but is probably also more characteristic of strata of relatively fine grain than of the most productive water-bearing beds.

It appears that the spectacular discharge of artesian water from the Dakota sandstone for more than half a century has been supplied to a great extent from storage, largely as a result of the elastic or compressive properties of the system. It remains to be determined whether the more moderate withdrawals that are likely to be made in the future will be replaced by recharge or will result in further progressive depletion. The 800-foot sand in the Atlantic City area has yielded water freely for several decades and is currently yielding several millions of gallons a day. It shows encouraging recovery of head whenever the rate of pumping from wells is diminished. However, a thirteen-year record obtained by the investigators in that area seems to show that the regional cone of depression is still expanding, and that with the resulting compression some water is still being taken from storage. Other great artesian sandstones, such as those which for many years have furnished the water supplies of Memphis and Houston, are known to have large annual recharge, but nevertheless further records are needed to determine definitely the source of the current pumpage—to what extent the pumped water is replaced by recharge and to what extent it is derived from storage by the further development of the regional cones of depression.

About 6,500 public waterworks in this country are supplied from wells. Many of these obtain their water from surficial formations with true water-table conditions and many others from recognized artesian formations. However, there is another large group of waterworks that are supplied from aquifers, largely in the glacial drift, that are not usually regarded as artesian and yet underlie more or less effective confining beds and are recharged by somewhat devious percolation of the ground water. More attention ought to be given to the problems of depletion and safe yield of these aquifers of intermediate character.

EMERGENCE OF HYDROLOGY AS A RECOGNIZED SCIENCE

The hydrologic cycle, being of major scientific and practical interest, has received the study of a large number of scientists, most of whom have not called themselves hydrologists. In this country the Weather Bureau long ago established a comprehensive and systematic program that has resulted in the accumulation of a great amount of base data on precipitation and other weather conditions, the value of which is beyond estimation. The Geological Survey has developed a thorough technique for gaging streams and has accumulated a remarkable body of systematic and exact data on stream flow. By systematic work through many years it has also made substantial achievements in the chemical analysis of the natural waters, in a general survey of the ground-water conditions, and in the development and application of quantitative methods in ground-water investigation.

In addition to the work of these two scientific bureaus of the Federal Government, there has been a vast amount of work by a great number of governmental and private agencies and individuals that has contributed in many ways to the base data and to the methods and principles of hydrology. Thus many hydraulic engineers have devoted much of their time not to engineering work at all but to scientific research relating to the natural waters; thus, also, many other scientists, such as soil scientists, agronomists, geologists, botanists, and foresters, have made distinct contributions to hydrology. There has, however, been a lack of coordination, and developments have been made which have had unfavorable effects that were not foreseen because the scientists and engineers concerned did not have an adequate appreciation of the unity and complexity of the hydrologic cycle.

In recent years there has arisen a wholesome recognition of hydrol-

ogy as a comprehensive science, and a general effort has been made to correlate the different aspects of the subject. This trend has found expression and stimulus in the organization, six years ago, of the Section of Hydrology of the American Geophysical Union. More recently an attempt has been made through the efforts of the Mississippi Valley Committee, the National Resources Committee, the State Planning Boards, and other agencies to evaluate objectively the manifold works of man that have affected the hydrologic cycle at some point and to attain a clearer perspective for the future. Thus progress has been made in an appreciation of the sensitivity of our water supply to many complex controls. Looking to the future, we must insist that engineering works or other developments shall be undertaken only after their hydrologic consequences have been fully studied, and we must resolutely set ourselves the task of building a science of hydrology that will be adequate for the responsibilities that are involved.

CHEMISTRY.—*Hydrogen ion concentration and the formation of copper complexes.*[1] K. J. MURATA, U. S. Geological Survey. (Communicated by R. C. WELLS.)

The exact function of the alcoholic hydroxyl groups of hydroxy acids in the formation of complex compounds with metals has become clarified in recent years by the physico-chemical investigations of Smythe and Schmidt (1) and of Smythe (2). Although several chemists working with these substances still ignore the role of the hydroxyl groups, there can be little doubt that the metal atoms displace hydrogen from them, especially from those in the alpha position, and establish covalent links between themselves and the remaining oxygens. The present trend in the interpretation of most of these substances is to consider them as chelated complex compounds, the "innere Komplexe" of Werner. Wark and Wark (3) who have made extended researches on the copper complexes are inclining toward this view. The modern electronic theory of valency provides a physical basis for Werner's coordination number, and emphasizes the importance of this secondary valence in complex formation. Other viewpoints are held by Mathieu (4) and by Dumanski and Chalisev (5).

As discussed by Smythe, the metal atoms in displacing hydrogen from the hydroxyl groups are merely enhancing a tendency toward acidic dissociation already possessed by the latter. Two interesting studies of the acidic nature of polyols (sugars) which have been

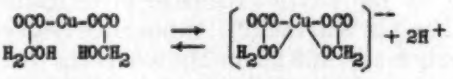
[1] Published by the permission of the Director, U. S. Geological Survey. Received January 15, 1937.

recently reported are those of Urban and Shaffer (6) and of Ambler (7).

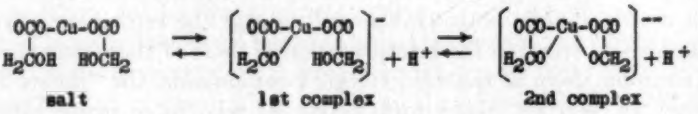
Inasmuch as hydrogen ions are liberated when complexes of this type are formed, the pH of the medium would be expected to have a profound influence on the progress of the reaction. Smythe and Schmidt explored the lower and upper pH limits of stability of different iron complexes. But there is evidence that the pH has an even more intimate action than merely setting these boundary conditions. The mechanism of complex formation outlined by these investigators can be represented for the cupric glycollate complex by equation (a). The bond between copper and the carboxyl groups in the parent salt is very likely one capable only of slight dissociation, like that found in copper malonate by Riley and Fisher (8) and in several tartrates of the transition elements by Mathieu (4). When a certain threshold pH is attained, according to the scheme of Smythe and Schmidt, the two hydrogens of the hydroxyls are simultaneously ejected, and a quadricovalent copper complex anion is formed.

The object of this paper is to discuss evidence indicating that the two alpha hydroxyls are not dissociated simultaneously but successively, thus giving rise to two different complexes which are stable in different pH ranges. See equation (b).

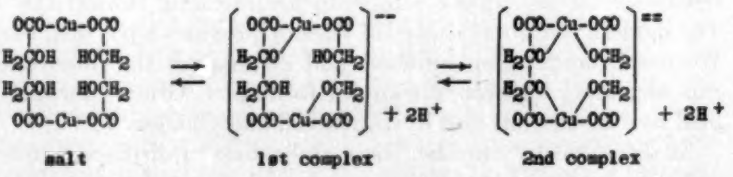
(a)



(b)



(c)



The instant that one of the hydroxyls loses a hydrogen ion, the symmetry of the molecule is lost and a stepwise dissociation becomes a possibility.

The report by Pickering (9) of a monopotassium cupriglycollate

complex from a faintly alkaline solution and a dipotassium compound from a strongly alkaline solution favors this view. However, a more satisfactory proof is to be found in certain cupritartrate complexes, which will next be briefly discussed.

THE CUPRITARTRATE COMPLEXES

Of the great number of different compounds of copper and tartaric acid that have been reported, attention will be confined to those which contain one atom of copper per mole of tartrate radical. These comprise a series which has been most recently examined by Gabiano (10) and by deMallemann and Gabiano (11), who studied their remarkable optical properties.

The first of two different complexes is formed when a sufficient base is added to the salt, cupric tartrate, to just dissolve a given quantity of it. On the basis of partial analyses, Gabiano has assigned to it the formula, $NaCuC_4H_4O_6 \cdot 2H_2O$.

The second complex is obtained in crystalline form from solutions containing larger amounts of the base than required for the first complex. deMallemann and Gabiano, by partial analyses, have fixed its composition as $Na_2CuC_4H_4O_6 \cdot 2H_2O$. It has a deeper bluish color than the first complex.

Copper tartrate differs from the tartrates of other divalent metals studied by Mathieu in that it does not yield an insoluble basic compound as the alkali is added to it. In this respect it behaves like chromium tartrate investigated by him (12) and by Hakamori (13).

Packer and Wark (14), several years prior to the researches of Gabiano, studied in great detail what has been called in this paper the first complex. They made complete analyses of their crystalline compound, and found the composition to be $(NaCuC_4H_3O_6)_3CuO \cdot 11H_2O$. Though this work has been criticised by Dumanski and Chalisev (5), subsequent checks (15) indicate that the result is essentially correct. The 1:1:1 ratio of Na:Cu:T seems to hold both here and in Gabiano's formula, though the discrepancy of $\frac{1}{3}$ CuO cannot be accounted for satisfactorily. It is highly desirable that the refractive indices and other optical properties of such synthesised materials be recorded so as to facilitate their identification by later workers. The findings of Packer and Wark are of special theoretical importance however, because they demonstrate that, in a certain pH range, one of the two alpha hydroxyl groups of the tartrate radical is dissociated while the other is still intact. This fact offers strong support to the hypothesis of stepwise dissociation for these hydroxyls briefly outlined above.

The molecular weight determinations carried out by Kahlenberg (16) show that the first complex is a double molecule. This work has not received the attention that it deserves.

The extensive researches of Bullnheimer and Seitz (17) on the second complex present at higher alkalinities seem to have successfully avoided the sources of error which arise from the instability of this substance, and which have been clearly set forth by deMallemann and Gabiano. Complete analyses by them gave $Na_2CuC_4H_2O_6 \cdot 2H_2O$. This differs from the formula given by deMallemann and Gabiano to the extent that the two hydrogens of the hydroxyl groups are lacking, a result to be expected on the basis of chelate ring structures for these complexes, and one which the partial analyses of the latter workers could not reveal. A mechanism for the formation of these complex copper tartrates, which emphasizes the successive dissociation of the hydroxyl groups, is outlined in equation (c) above.

When one adds the base to cupric tartrate in increasing amounts, he notes the color changes that appear as the first and the second complexes form. But beyond a certain amount there is no further deepening of the blue color. This is seen to be a consequence of the second complex, which forms through the dissociation of the second alpha hydroxyl, attaining a stable and ultimate quadricovalent structure. Any excess of a base is without effect, at least so far as the chromophoric copper atoms of the complex are concerned.

The concern of the chemist when he adds an alkali to the solid cupric salts of these hydroxy acids or to solutions of them to form the complexes should not be the molecular ratio between the alkali and copper, but rather the pH of the system. The value of some of the stoichiometric equations used to account for the formation of complexes is doubtful. The role of the base is not to take a direct part in the synthesis of a complex but to alter the nature of the medium and the reactants so that the synthesis may proceed.

Whether or not the copper atoms in the first complex are manifesting the unusual covalency of three or whether the fourth covalency is satisfied by a molecule of water cannot be decided until more reliable means of determining coordinated water of this kind are established, and the hydration of the other constituents becomes known. That the quadricovalent copper of the second complex has a planar configuration becomes very probable in the light of recent researches of Cox and coworkers (18). The different cis and trans arrangements which the isomeric tartrates can form may account for the marked differences in their stability.

A survey of the cupric complexes of several alpha hydroxy acids indicates that the stepwise dissociation of the hydroxyl groups is a general characteristic. For example, Pickering's (19) "Potassio-cupric Hydrogen Citrate" containing 5 atoms of potassium and 1 of copper is very likely the first complex, and his "Potassium beta-Cupri-citrate" with 6 atoms of potassium and one of copper the second complex for this acid. Any study of the equilibrium constants of complex substances of this sort must therefore discriminate between the two kinds that occur in the different pH ranges. Potentiometric pH titration curves usually fail to show any distinct breaks however, and manifest a smooth slope characteristic of weak polybasic acids.

CONCLUSION

Evidence pointing to a stepwise dissociation of the hydroxyl groups in complex formation between copper and alpha hydroxy acids is discussed. In general, as a result of this behavior two different simple cupric complexes may exist, each in a different pH range.

A modification of the mechanism for complex formation outlined by Smythe and Schmidt is proposed.

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PALEONTOLOGY.—Clistocrinus, *a new Carboniferous crinoid genus.*[1] EDWIN KIRK, U. S. Geological Survey.

Through the kindness of Dr. G. H. Girty, of the U. S. Geological Survey, I have been given the opportunity of studying and describing an interesting new crinoid genus from the Carboniferous of South-

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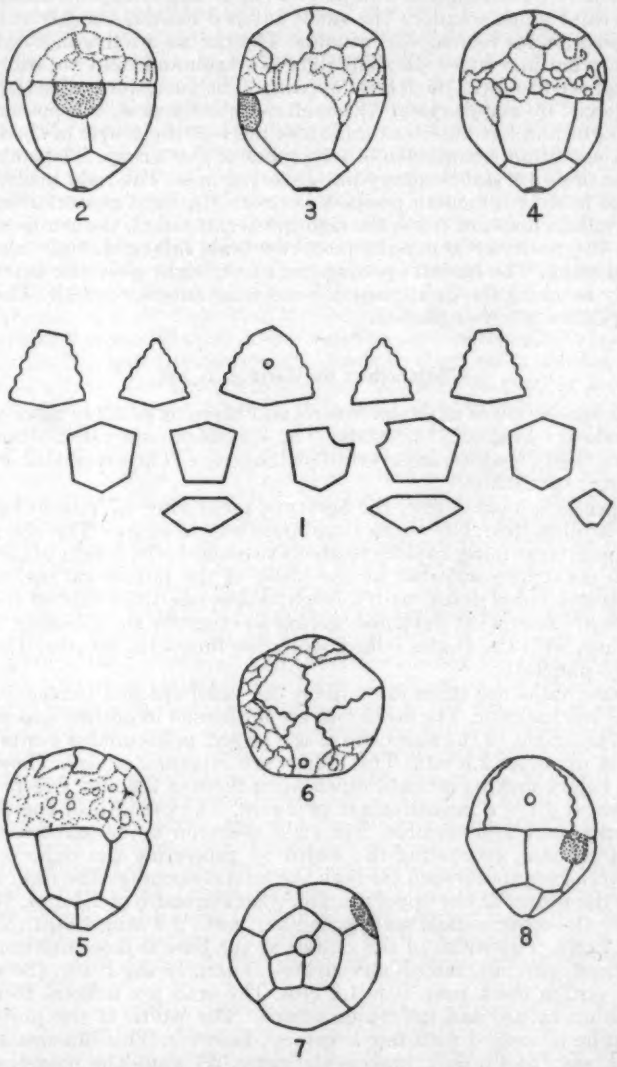
eastern Alaska. This genus, for which the name *Clistocrinus* is here proposed, belongs to a group of small crinoids of anomalous structure which in recent years has been found to have a wide geographical distribution and to range throughout the Carboniferous and up into the Permian. As now known, these crinoids have been found in the Visean (Lower Carboniferous) of Belgium and England, and the upper Mississippian of the United States, the Pennsylvanian (essentially the European Upper Carboniferous) of the United States and Alaska, the Permo-Carboniferous of Russia, and the Permian of Timor and the United States. *Clistocrinus*, coming as it does from the lower Pennsylvanian of Alaska, is of very great interest both on account of its geographic and stratigraphic position. Structurally *Clistocrinus* furnishes an intermediate form in the series of these crinoids as known.

Clistocrinus, n. gen.

The genotype is *Clistocrinus pyriformis*, n. sp.

Before giving a description of the crinoid, certain points of terminology and orientation will briefly be considered in order to avoid confusion. The theca is composed of three circlets of plates. According to Wanner's usage these would be named, as in a dicyclic crinoid, infrabasals, basals, and orals, the radials being absent. For convenience in the present case I prefer treating the form as a monocyclic crinoid, calling the same circlets of plates basals, radials, and orals, respectively. According to Wanner's thesis, such a form as this is derived from a dicyclic crinoid with four circlets of plates by the elimination of one circlet, the radials. I believe the reverse is true and that the four-circlet type is derived from the three circlet by an intercyclic interpolation of a fourth ring of plates which become known as radials. Were this the only evolutionary possibility, Wanner's terminology would still be applicable. I think, however, that the median circlet of plates of the three-circlet type is potentially either a basal or a radial ring and feel that it is less confusing to use a nomenclature based on monocyclic structure in such crinoids as have the orals alternating with the plates of the second range. To all intents and purposes, irrespective of potential dicyclic structure, these crinoids are monocyclic. In orienting the theca I call the large hydropore-bearing oral the posterior and arrange the other plates accordingly. Wanner also calls this oral posterior, but according to his interpretation it then would have a radial position in this form as in *Acaraiocrinus*, and the orientation of the dorsal cup would be arbitrary, his posterior "basal" being 36° out of line with the posterior oral. The difference of orientation between Wanner and myself must be borne in mind when reading his descriptions. The large lateral opening lying in the radial-oral plane which has universally been called the anal opening may be such, but I doubt it. The opening piercing the posterior oral, which is probably the anal opening, I shall call the hydropore, a somewhat equivocal term but in conformity with current and past usage.

The following brief diagnosis of the genus will give the salient features of the form, the more detailed description being found under the description of the type species.



Figs. 1–8.—*Clistocrinus pyriformis*, n. sp. 1, plate diagram. 2, view from right posterior interradius showing the lateral opening. 3–5, views of same specimen revolving the specimen progressively to the left. 6, tegminal view. 7, basal view. 8, another somewhat smaller specimen, posterior view showing the position of the hydropore. Figs. 2–8 are approximately ×6.

The basal units are three in number, two large and of approximately equal size, the third much smaller. The small unfused basal is the left anterior, a normal position for monocyclic crinoids. The radials are five in number and vary somewhat in relative size. The right posterior and right anterior radials are invaginated to form the lateral opening. The posterior oral is the largest and is pierced by a hydropore. Although not clearly seen, the posterior oral and the right and left anterior orals alone meet at the center of the tegmen. This is a condition common to other genera of this group. The sutures between the orals are sinuous, very like *Embryocrinus*. The right posterior oral instead of holding a median position between the right posterior and right anterior radials does not touch the right posterior radial, the common suture between the posterior and right posterior orals falling directly above the lateral opening. The lateral opening lies in the right posterior interradius, unequally notching the right posterior and right anterior radials. The superjacent orals are not invaginated.

Clistocrinus pyriformis, n. sp.

Of this species three adult specimens and three or possibly more younger individuals are available for study. The specimens are calcified and were found in a richly fossiliferous crystalline limestone. The sutures show clearly in the larger specimens.

The species is a small one, the holotype measuring 4.7 mm in height by 4.2 mm in diameter. The theca is subpyriform in shape. The sides of the dorsal cup diverge fairly rapidly to about two-thirds the height of the radials and then constrict somewhat at the plane of the radial-oral contact. The tegmen is a rounded dome, with a height about one-third that of the theca. The orals are somewhat flattened, giving the tegmen an obscurely facetted appearance, with the angles falling along the inter-oral sutures. The plates are finely punctate.

The basal units are three in number, the small unfused pentagonal basal being the left anterior. The other two are hexagonal in outline and subequal in size. The height of the basal cup of the largest individual is 1 mm and its maximum diameter 2.3 mm. The radials are subequal in size. They have a uniform height looking straight down upon them of 2.2 mm, except the anterior, which gives a measurement of 2 mm. The breadth of the plates at their upper margin is variable. The right posterior is the narrowest with a width of 1.8 mm, estimating the width by projecting the right posterior-right anterior suture upward through the lateral opening. The right anterior radial is the widest at the upper margin, with a breadth of 2.7 mm. Measurements for the other radials read as follows: ant., 2.3 mm; l. ant., 2 mm; l. post., 2.2 mm. The width of the radials at the base is more uniform, the r. post., r. ant., and ant. radials measuring 1.5 mm. In the l. ant. the width is 1.4 mm, and in the l. post. it is 1.2 mm. The orals are difficult to measure owing to curvature and indistinct sutures. The width of the plate at the base can be measured with fair accuracy, however. This dimension on the r. ant., l. ant., and l. post. orals is the same, 2.7 mm. The posterior oral is by far the largest, with a width of 3.3 mm, while the r. post. oral is narrower than the first three noted, with a width of but 2.5 mm. The apposed faces of the orals are coarsely crenulate, as in *Embryocrinus* and *Coenocystis*. The hydropore cannot be located with certainty in the larger specimen illustrated, but its probable situation is indicated in figure 6 and was drawn in mainly to identify the hydropore-oral. The hydropore shows clearly in the

specimen illustrated as figure 8 and in one other. In the specimen not figured the hydropore is much nearer the apex of the oral. The hydropore shows as a pit, rather than as elevated pimple, as is often the case. In the larger specimen the pit is surrounded by a smoothly rounded ridge.

The lateral opening is of relatively large size, having a maximum height of 0.9 mm and a width at the oral-radial plane of 1.2 mm. It lies in the right posterior interradius, unequally cutting into the right posterior and right anterior radials. Of the total width, approximately 0.8 mm lies within the right posterior radial and 0.4 mm within the right anterior radial. The opening does not cut into the superjacent orals as is the case in several genera. One would expect the lateral opening to be covered entirely by the right posterior oral. Such is not the case, however. The posterior oral extends beyond the median line of the right posterior radial and meets the right posterior oral at a point about midway of the lateral opening.

On the surface of the tegmen of the largest individual are irregular superimposed raised areas. When first seen these areas were thought to be extraneous growths. Being restricted almost entirely to the tegmen, apparently having the structure of crinoid stereom, and similar but smaller areas being found on other specimens, it seems probable that they are structures of the crinoid itself. As seen the surface of these areas is covered with irregularly disposed suboval to subcircular depressions. In general appearance the depressions are similar to the pits for the reception of epithecal brachioles in some of the more primitive cystids, but the resemblance is probably superficial. There would appear to be no reason for calcified exothecal extensions on crinoids of this type. The pits are sometimes thickly clustered and sometimes fairly well separated. It is difficult to render the structures in a drawing, even to the extent of delimiting the areas themselves. The outline shown in figures 2 to 6 are intended only approximately to give the general size and distribution of the areas. In general these patches of stereom are most numerous near the periphery of the theca and along the inter-oral sutures.

The areal distribution of the epithecal structures in the largest specimen shows an almost continuous peripheral band at the base of the orals, with the greatest development along the inter-oral sutures. A large patch lies directly above the lateral opening, extending on both sides of the post.-r. post. oral contact. It extends upward along the suture to about one-half the height of the orals. From this patch a narrow band extends to the right horizontally and just above the radial-oral plane to another large patch on the r. ant.-l. ant. oral contact. This patch is clearly defined, and its surface rises well above that of the orals. It extends upward to about two-thirds the height of the orals. From this patch a broad irregular band extends across the l. ant. and l. post. orals to slightly beyond the l. post.-post. oral suture. The band broadens somewhat at both the l. ant.-l. post. oral and l. post.-post. oral contacts. This band lies at times somewhat above the radial-oral plane.

In two other somewhat smaller individuals the surface of the theca is not as well preserved, but structures suggesting similar epithecal deposits can be seen. As shown the areas are discontinuous and much smaller than in the largest specimen. Here again the main concentration of superficial stereom is along inter-oral sutures. In two small specimens the plate sutures cannot be seen, and the separation of tegmen and dorsal cup must be made arbitrarily. The pits in these specimens are relatively large, and apparently the epithecal areas extend onto the dorsal cup.

The stem cicatrix is round and has a diameter of 0.5 mm.

Picked out of the broken limestone fragments, and associated with the large specimens of *Clistocrinus pyriformis*, are five small subovate to capsule-shaped specimens that appear to be the young of the crinoid. Broken out of a dark crystalline limestone and not subjected to weathering, it is not possible to see plate sutures in all of them. One can be reasonably certain of at least three of the specimens, however. The tegmen and dorsal cup can be recognized, and the lateral opening and the columnar attachment can be identified with a fair degree of certainty. A fourth specimen is so similar to the other three as to render its identification reasonably sure. The fifth and smallest specimen is of uncertain placement. All the specimens agree in having a height in excess of the diameter. In the smaller specimens the diameter is approximately 0.8 the height. With increasing age the diameter approaches 0.9 the height, and this appears to hold as an average for the larger specimens. The proportions of tegmen and dorsal cup appear to be reasonably constant. In the younger specimens the base is more rounded, however, and it is difficult to distinguish one end of the theca from the other.

Horizon and locality.—The locality as given by the collector, A. F. Buddington, is "Northwest end of large island at head of Saginaw Bay, Kuiu Island, on east side; 40-foot bed of limestone intercalated in series of interlayered chert, slaty quartzite, and cherty limestone." Girty[2] gives an extensive faunal list of the associated fossils and on page 116 gives his opinion as to the age of this and similar faunas. His conclusion was tentatively to make the fauna upper Mississippian in age, though recognizing strong Pennsylvanian affinities. At my suggestion, L. G. Henbest examined the foraminifera from this locality, and his general conclusion[3] is that these fossils favor an assignment of the fauna to the Pennsylvanian. Girty[4] holds that although the evidence for a Pennsylvanian age does not appear much stronger than in 1929, the evidence for a Mississippian assignment seems somewhat weaker. His general conclusion is "The Alaskan fauna, I am inclined to believe, will prove to be of Pottsville age, or at least early Pennsylvanian, but I cannot say that the proof is at present extant." There are two other crinoid genera in the material. *Synbathocrinus* is indeterminate as to age. The other is a small crinoid which, though not typical, would be referred to *Delocrinus*, a Pennsylvanian genus. On the whole it would appear best to consider the fauna lower Pennsylvanian in age.

Types.—The cotypes and other specimens studied are in the collections of the U. S. National Museum, No. 94441.

Structurally we see in *Clistocrinus* an intermediate evolutionary stage between the Mississippian *Lageniocrinus* and the Permo-Carboniferous (Russia) and Permian (Timor) *Acariaiocrinus* (*Streptostomocrinus*). In another paper I am redescribing *Lageniocrinus*, based on a study of de Koninck's type specimen of *L. seminulum*. In *Lageniocrinus* there is a lateral ("anal") opening notching the upper corners of the two plates of the second range, one below the hydropore-oral and the one to the right. The orals are in alignment with the plates of the second range. In *Clistocrinus* we find the orals shifted to the left relative to the plates of the dorsal cup, becoming

[2] GIRTY, G. H., in BUDDINGTON, A. F., and CHAPIN, THEODORE, *Geology and mineral deposits of southeastern Alaska:* U. S. Geol. Survey Bull. 800: 113. 1929.

[3] Personal communication, August 29, 1936.

[4] Personal communication, November 11, 1936.

"interradial" in position. The lateral opening is larger and has migrated somewhat to the left. In *Acariaiocrinus* the orals are "interradial" in position, and the lateral opening has migrated still further to the left, holding a median position on the right posterior "radial."

In some of the genera of this group of crinoids it has been assumed that the orals could be opened and closed. There has been no evidence for this, but anyone handling the material would, I think, come to this conclusion. I have very good evidence in the case of *Coenocystis*. Here there are five suboval pits, each at the center of the distal face of a plate of the second range ("radial"). Above each pit is a cavity excavated in the superjacent orals and equally shared by them. At the proximal angles of the orals are apophyses that project downward and bear against the inner wall of the dorsal cup when the orals are closed. It is obvious that we have here an articulating structure of rather complex type. In the case of *Clistocrinus* we have two difficulties. One is that the inter-oral suture between the posterior and right posterior orals is in line with the large lateral opening, and the proximal corners of these orals involved have no bearing surface. Obviously with the corners lacking support and the total bearing surface cut down these plates would have poor but perhaps adequate articulating surfaces. The other difficulty is the presence of the patches of stereom partially covering the inter-oral sutures and effectively soldering the oral dome into an immovable unit. It is possible that these pitted areas of superimposed material were not laid down by the crinoid, but the evidence at hand seems in favor of such an explanation. An examination of 10 well-preserved specimens of *Embryocrinus* shows nothing comparable in that genus, nor has anything of the sort been seen in a number of specimens of *Coenocystis*, though here the preservation, owing to silicification, makes the evidence less satisfactory. The only thing to do is to await more material to confirm or disprove the apparent structure. It would be of great importance, however, to know that such a crinoid could function with its orals firmly closed. In such case it would appear necessary to consider the lateral opening as an oral opening. I favor this view.

Of great importance in the orientation of the crinoids of this group and the Allagecrinidae as well, and in some cases the only reliable criterion, is the evidence offered by the orals. This does not seem to have been recognized. The arrangement and shape of the orals seems to be invariable. The posterior oral is the largest. Often the hydropore can be recognized without doubt, but fortuitous pitting and secondary alteration of the surface of specimens as small as these may lead one astray. The posterior oral may, however, be recognized by its pentagonal outline, and careful examination will usually show its distal portion formed of two faces meeting at an obtuse angle. The right and left anterior orals are large, quadrangular in outline and make contact with the posterior oral with their obliquely truncated distal faces. The right and left posterior orals are relatively small, triangular in outline and do not reach to the center of the tegmen. A recognition of these facts should prevent the preparation of drawings and plate diagrams that show the orals as five subequal triangular plates or with the right and left anterior orals truncated in the wrong direction. A modification of this typical structure is found in *Embryocrinus* and possibly elsewhere. Here the apical portion of the posterior oral forms an obtuse re-entrant angle, with a median projection. The apical portions of the right and left anterior orals fit into the re-entrant and in this case are not obliquely truncated.

BOTANY.—*A new type of heterobasidiomycete.*[1] G. W. MARTIN, State University of Iowa.

The fungi included in the order Tremellales, in the wide sense, are of peculiar interest because they may be regarded as constituting the plexus from which has developed, on the one hand, the rusts and smuts, and, on the other, the homobasidiomycetes. For this reason, the finding of an undoubted member of the order possessing a characteristic suggestive of certain phenomena long known to occur in the smuts is worthy of more extended comment than might be justified were it merely an addition to the known genera and species of the group.

The fungus in question was found to be common in western Panama, growing on fallen trunks and stumps in the mountain forest bordering the upper Rio Chiriqui Viejo. In appearance it suggests a large, white and rather soft *Tremella*, but microscopic examination shows it to be a member of the Auriculariaceae, with unique basidia and spores. It is difficult to believe that so large, common and conspicuous a form has not been previously noted, but, if it has, I have been unable to find any recognizable description. As there seems to be no known genus into which it may be placed, it becomes necessary to erect one for it.

Syzygospora Martin, gen. nov.

Fructificatione sessile, gelatinosa; basidiis clavatis, transverse uniseptatis, loculis singulis monosporium gerentibus; sporis coalescentibus ante disjunctionem.

Basidiocarp sessile, gelatinous; hymenium covering entire exposed surface; basidia bluntly clavate, transversely septate into two cells, each cell producing a single basidiospore on a short sterigma; basidio-spores fusing in pairs before detachment. Type species, *S. alba*.

Syzygospora alba Martin, sp. nov.

Fructificatione sessile, late effusa, undulata vel subcerebriformia, alba, gelatinosa demum deliquescente, attingente 10×5×2.5 cm; sicca fulva, cornea; basidiis clavatis, 8–15×3.5–4μ, transverse uniseptatis, loculis singulis monosporium gerentibus; sporis subglobosis, coalescentibus ante disjunctionem, demum cylindraceis post fusionem, 5–6×2.8–3.2μ.

Basidiocarp sessile, broadly effused, undulate to subcerebriform, pure white, soft gelatinous, with long soaking becoming deliquescent, up to 10 cm long by 5 cm broad by 2.5 cm thick; dark brown and horny when dry; hymenium composed of basidia borne in fascicles at the tips of branching, radiating hyphae, forming a dense palisade layer covering the entire surface; basidia bluntly clavate, 8–15×3.5–4μ, becoming transversely septate into two cells, the distal cell blunt and approximately isodiametric, the basal cell longer and attenuated toward the base, each cell producing a globose

[1] Received January 9, 1937.

basidiospore on a short sterigma, that of the distal cell borne at the basal end just above the septum, that of the basal cell borne at the distal end just below the septum and adjacent to the other, the two basidiospores fusing before attaining full size and finally breaking off as a single oval, cylindrical or slightly dumb-bell shaped spore 5–6×2.8–3.2μ.

Panama: Prov. Chiriqui. Valley of upper Rio Chiriqui Viejo, alt. 1600–1800 m., June–July 1935. G. W. M. 2449 (Type, in herb. State Univ. Iowa), 2167, 2517, 2547, 2575.

The generic name is derived from *σύζυγος, yoked together*, and *σπορά, spore.*

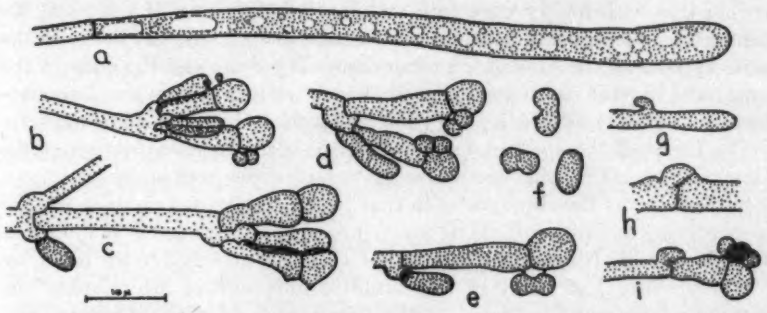


Fig. 1.—*Syzygospora alba*, n. gen. and sp. a, cystidium. b, cluster of four basidia, two bearing spores. c, tip of large axial hypha bearing cluster of three basidia, one preparing to produce spores, and two clamp connections, both proliferating, one to bear a single basidium, the other, a lateral branch which bore at tip a cluster of basidia similar to b, which was produced at the next lower septum. d, cluster of three basidia, the center one showing early stage of fusion of spores. e, two basidia, the larger one showing spores in late stage of fusion. f, three fused and detached spores two showing evidence of origin; the bulk of the spores resemble the third. g, tip of axial hypha showing beginning of clamp connection. h, clamp connection from basal region of axial hypha. i, basidium possibly bearing four spores. All drawings made with aid of camera lucida at magnification ×2436, and reduced in reproduction to ×1200.

When soaked, the fructifications become rather dingy white and waxy-gelatinous, then soft, but do not regain their original color and size. A microtome section through a portion of a soaked specimen, hardened in formalin and imbedded in paraffin, shows the hyphae aggregated into thin anastomosing strands separated by large open spaces, the whole suggesting a structure resembling that of a sponge. The internal hyphae are of two sorts, extremely irregular, tortuous hyphae of varying size, and large straight ones, 3–4μ in diameter, which radiate outward in all directions and by repeated branching give rise to the basidiophores, which are mostly 1. 5μ–2μ in diameter. Clamp connections are abundant, being visible at almost every septum, including those at the base of the basidia. The basidia themselves are borne singly, or in unilateral cymose tufts of two to four, the successive basidia after the first usually arising by proliferation from the clamp connection at the base of the next older basidium, essentially in the manner reported by Rogers[2] for *Sebacina prolifera.*

[2] Mycologia **28**: 347–362. 1936.

A small number of basidia were observed which seemed to bear two pairs of spores. When carefully focussed, some of these resolved themselves into two superimposed basidia, others seemed to be instances where a loose spore had become attached to the side of the basidium, but in a very few instances there seemed to be four spores, fused or unfused, actually present. If this interpretation is correct, it is probably to be regarded as an aberration such as is characteristic of the Tremellales.

In addition to basidia, the hymenium includes a small number of clavate, hyphal tips with highly vacuolate and somewhat refringent contents, attaining 80μ in length and 5μ in diameter near the tips. They are borne on the same hyphae as the basidia. In some cases they represent the ends of the large axial hyphae bearing the basidiophores, while in others they originate amongst a cluster of basidia. They are evidently to be regarded as cystidia.

The fusion of the spores must result in the immediate restoration of the dicaryon phase. This phenomenon seems to be distinct from anything known heretofore in the Basidiomycetes in that fusion results in a distinct, diploid spore serving as a disseminule. It must, however, be regarded as homologous with the familiar fusion of sporidia either while still attached to the basidium ("promycelium") of many of the smuts or immediately after separation, first announced and illustrated by the Tulasnes[3] and later by DeBary, Brefeld and many others. It is perhaps even closer to the fusion between the cells of the basidium as demonstrated by Rawitscher for *Cintractia Montagnei*.[4] In the smuts, however, the smut spore, or probasidium, is the primary disseminule, and the fusion product either grows directly into a mycelium or proceeds to develop secondary basidiospores which are forcibly discharged and then function as disseminules.[5] The fusion of basidiospores in *Syzygospora* is significant as illustrative of a tendency in the group which may have been modified and developed in the smuts and adapted to their highly specialized ecological requirements.

ZOOLOGY.—*North American monogenetic trematodes. I. The superfamily Gyrodactyloidea.*[1] EMMETT W. PRICE, U. S. Bureau of Animal Industry.

The monogenetic or ectoparasitic trematodes comprise a wide variety of more or less bizarre flatworms occurring on fishes and other aquatic animals. These forms are most commonly encountered on the skin and gills of marine and fresh-water fishes. Several species occur in the mouth and upper respiratory tract of turtles and in the urinary bladder of turtles and frogs. A few have been found on crustaceans and cephalopods, and one species has been reported from the eyes of

[3] Ann. Sci. Nat. Bot. IV **2**: 157–159. 1854.
[4] Ber. deut. bot. Gesell. **32**: 281–287. 1914.
[5] BULLER. *Res. on Fungi*, **5**: 207–278. 1933.
[1] Received January 29, 1937.

an aquatic mammal. The literature dealing with this group of trematodes is fairly extensive, although only a few papers have appeared which may be regarded as monographic in scope. The most important are those by Braun (1889–1893), Saint Remy (1891a and b, 1892, 1898), Goto (1894), Johnston and Tiegs (1922) and Fuhrmann (1928).

The first monogenetic trematode from a North American host was described as an "insect" by La Martinière (1787), and was found on the skin of a fish collected somewhere between Monterey Bay, California, and Nootka Island. The true nature of this "insect" was determined by Bosc (1811). Since that time more than 40 papers have appeared which deal either wholly or in part with North American representatives of the order Monogenea. The most extensive studies of these forms were made by the late Dr. G. A. MacCallum (14 papers appearing from 1913 to 1931), and by Stunkard (1917), Mueller (1934, 1936) and Mizelle (1936).

This paper, which is the first of several to appear under the general heading of *North American monogenetic trematodes*, is limited to the superfamily Gyrodactyloidea. Subsequent papers will deal with other major groups and will appear in sequence. In all of these papers will be given diagnoses and keys for all groups as far as genera, and when taken together these papers will represent a revision of the entire order Monogenea. Under each genus is given a list of all species known to belong to that group. However, no attempt has been made in each instance to pass judgment on the validity of the exotic representatives of these genera. The species of which detailed descriptions are given are those from this continent that have been inadequately characterized and those in which important characters have been overlooked or misinterpreted. A few new species have been included, but no particular effort has been made to obtain new forms since the mere describing of new species is regarded of minor importance as compared with redescriptions of imperfectly known old species.

This revision has been made possible through access to the extensive collections of MacCallum, Linton and others, which are deposited in the U. S. National Museum. The writer is indebted to Drs. J. E. Guberlet, University of Washington; Harold Heath, Stanford University; Edwin Linton, University of Pennsylvania; H. W. Manter, University of Nebraska; John D. Mizelle, University of Illinois; Justus F. Mueller, Syracuse University; H. S. Pratt, Haverford, Pa.; H. W. Stunkard, New York University; and H. J. Van Cleave, University of Illinois; as well as to Drs. P. D. Harwood, W. H. Krull, E. E. Wehr, and Mr. Allen McIntosh of the Zoological Division, U.

S. Bureau of Animal Industry, for supplying specimens not available in the U. S. National Museum Collections.

Order MONOGENEA Carus, 1863[2]

Synonyms.—Cryptocoela Johnston, 1865; Ectoparasitica Lang, 1888; Eterocotylea Monticelli, 1892; Heterocotylea Braun, 1893; Monogenetica Haswell, 1893; Heterocotylida Lahille, 1918.

Diagnosis.—Small to medium sized ectoparasitic flukes, with elongated to leaf-like bodies. Anterior end of body with or without haptors; posterior end always with a haptor, the haptor usually provided with hooks or suckers, or with both hooks and suckers. Mouth ventral or subterminal, at or near anterior end; pharynx always present, well developed; intestine single or double. Eyes present or absent. Excretory system double, opening dorsally through 2 symmetrically placed pores at or near level of genital aperture. Always hermaphroditic; genital apertures usually opening into a common sinus. Genito-intestinal canal present or absent. Uterus usually short; eggs few, frequently provided with polar prolongations. Development direct, i.e., without alternation of generations and without alternation of hosts; metamorphosis incomplete. Usually parasites of cold-blooded vertebrates or of crustaceans parasitic on vertebrates, rarely on cephalopods and mammals.

Odhner (1912) has proposed a division of the Monogenea into two suborders, Monopisthocotylea and Polyopisthocotylea, on the basis of the presence or absence of a genito-intestinal canal, and most authors have accepted Odhner's proposal. Fuhrmann (1928), however, recognizes three suborders, namely, Monopisthodiscinea, Monopisthocotylinea and Polyopisthocotylinea, the first two of these groups being the result of splitting Odhner's Monopisthocotylea into two suborders, while the third is equivalent to Polyopisthocotylea Odhner. The writer fails to see sufficient fundamental difference to warrant subdividing the Monopisthocotylea into two suborders, preferring to retain the groups as proposed by Odhner, and has proposed two superfamilies to replace the first two of Fuhrmann's suborders.

KEY TO THE SUBORDERS OF MONOGENEA

Genito-intestinal canal present.....Polyopisthocotylea Odhner
Genito-intestinal canal absent.....Monopisthocotylea Odhner

Suborder MONOPISTHOCOTYLEA Odhner, 1912

Synonyms.—Monocotylea Blainville, 1828; Tricotylea Diesing, 1850; Tristomeae Taschenberg, 1879; Oligocotylea Monticelli, 1903; Monopisthodiscinea Fuhrmann, 1928; Monopisthocotylinea Fuhrmann, 1928.

Diagnosis.—Anterior haptors present or absent, when present consisting of a weakly developed oral sucker, or of 2 lateral suckers not opening into oral cavity, or of 2 elongate depressions near anterior end of body with numerous small unicellular glands opening into them; when haptors absent, adhesive function supplied by cephalic glands opening singly at anterior

[2] Most authors credit the name of this order to Van Beneden (1858), but this seems to be an error. Van Beneden proposed a division of the trematodes into two major groups, "monogénèses" and "digénèses," the names being in the vernacular form. The first to use the name Monogenea for the order appears to have been Carus (1863).

margin of body or through one or more pairs of head organs. Posterior haptor disc-like, usually well developed, its ventral surface with or without septa, never bearing distinct suckers or clamp-like attaching organs, usually armed with 1 to 3 pairs of large hooks and a number (2 to 16) of marginal hooklets; large hooks frequently supported by transverse cuticular bars. Eyes present or absent. Genito-intestinal canal absent, except possibly in Protogyrodactylidae. Vagina present or absent.

KEY TO SUPERFAMILIES OF MONOPISTHOCOTYLEA

Posterior haptor armed; large hooks with supporting bars.....Gyrodactyloidea. Johnston and Tiegs
Posterior haptor armed or unarmed; when armed, large hooks without supporting bars.....Capsaloidea Price

Superfamily GYRODACTYLOIDEA Johnston and Tiegs, 1922

Diagnosis.—Anterior haptors absent; cephalic glands present, usually in 2 groups, 1 group on each side of pharynx, with ducts opening to exterior through 1 or more pairs of head organs. Posterior haptor disc-like, sometimes wedge-shaped, bearing 1 to 2 pairs of large hooks, the hooks almost always supported by 1 to 2, rarely 3, cuticular bars. Intestine sac-like or consisting of 2 branches with or without diverticula, the later, when present, short. Genital aperture median or submedian. Cirrus simple, cuticular, frequently with complicated cuticular accessory structure. Vagina present or absent. Vitello-intestinal canal rarely present. Oviparous or viviparous.

Type family.—Gyrodactylidae Cobbold, 1877.

KEY TO FAMILIES OF GYRODACTYLOIDEA

1. Viviparous.....Gyrodactylidae Cobbold
   Oviparous.....2
2. Vitello-intestinal duct present. Protogyrodactylidae Johnston and Tiegs
   Vitello-intestinal duct absent.....3
3. Anterior end of body expanded to form head lappets.....Calceostomatidae Parona and Perugia
   Anterior end of body not expanded to form head lappets.....Dactylogyridae Bychowsky

Family GYRODACTYLIDAE Cobbold, 1877

Diagnosis.—Small, elongated Monogenea, with 2 head organs. Haptor well developed, usually bearing 1 pair of large hooks (absent in Isancistrinae) and 15 or 16 marginal hooklets. Intestine branched, the 2 limbs not uniting posteriorly. Eyes absent. Male copulatory organ armed with a row of minute spines and usually with a triangular cuticular plaque. Ovary V-shaped, or lobed, posttesticular. Vitellaria absent or united with ovary. Vagina absent. Viviparous. Parasites of fishes, amphibians and cephalopods.

Type genus.—*Gyrodactylus* Nordmann, 1832.

Many authors, including Johnston and Tiegs (1922), Fuhrmann (1928), Froissant (1930) and Bychowsky (1933), credit the name of this family to Van Beneden and Hesse (1863), but these authors used the name "Gyrodactylides" and not "Gyrodactylidae"; the first to use the correct form of the family name appears to have been Cobbold (1877).

KEY TO SUBFAMILIES OF GYRODACTYLIDAE

Haptor with 2 large hooks and 16 marginal hooklets.....
.....Gyrodactylinae Monticelli
Haptor without large hooks but with 15 marginal hooklets.....
.....Isancistrinae Fuhrmann

Subfamily GYRODACTYLINAE Monticelli, 1892

Diagnosis.—Anterior end bilobed, each lobe with a head organ. Haptor circular, with 1 pair of large hooks and 16 marginal hooklets. Parasites of fishes and amphibians.

Type genus.—*Gyrodactylus* Nordmann, 1832.

Genus GYRODACTYLUS Nordmann, 1832

Diagnosis.—Characters of the subfamily.

Type species.—*Gyrodactylus elegans* Nordmann, 1832.

The genus *Gyrodactylus* contains the following species: *G. elegans* Nordmann, 1832; *G. groenlandicus* Levinsen, 1881; *G. gracilis* Kathariner, 1894; *G. medius* Kathariner, 1894; *G. rarus* Wegener, 1910; *G. fairporti* Van Cleave, 1921; *G. japonicus* Kikuchi, 1929; *G. cobitus* Bychowsky, 1933; *G. latus* Bychowsky, 1933; *G. parvicopula* Bychowsky, 1933; *G. cylindriformis* Mueller and Van Cleave, 1932; *G. elegans* vars. A. and B. Mueller, 1936; and *G. gurleyi*, n. sp. Of these species, *G. fairporti*, *G. elegans* vars. A and B, *G. spathulatus* and *G. gurleyi* are from North American fish hosts. *G. elegans* Nordmann has been reported from fishes in Maine by Atkins (1901) and in Washington by Guberlet, Hansen and Kavanagh (1927) but whether these reports indicate the occurrence of the European species by that name is open to question. The report by Cooper (1915) of the occurrence of *G. medius* Kathariner from North America is likewise questionable, as the description and figure given by Cooper indicate that he was dealing with some species other than *G. medius*.

In addition to the species listed above, reports of species of *Gyrodactylus* from North American fishes have been given by a number of writers, including Davis (1929) and Hess (1930) but no evidence is given in these reports that would enable one to determine the species involved. Recently Stunkard and Dunihue (1933) reported the occurrence of a species of *Gyrodactylus* on tadpoles of *Rana catesbeiana*, constituting the first report of a species of this genus parasitizing an amphibian.

Gyrodactylus gurleyi, n. sp. Fig. 1

Description.—Body elongate, 435 to 510μ long by 60 to 76μ wide, width about uniform throughout length of body proper; anterior end bifid and provided with 1 pair of head organs; cephalic glands present on each side of pharynx. Haptor circular, about 76μ wide, armed with 1 pair of large hooks supported by a delicate dorsal bar and a similar ventral bar, and with 16 marginal hooklets; ventral bar at level of proximal ends of large hooks. Large hooks 45 to 49μ long; marginal hooklets about 23μ long. Oral aperture ventral, about 75μ from anterior end; esophagus very short; intestinal

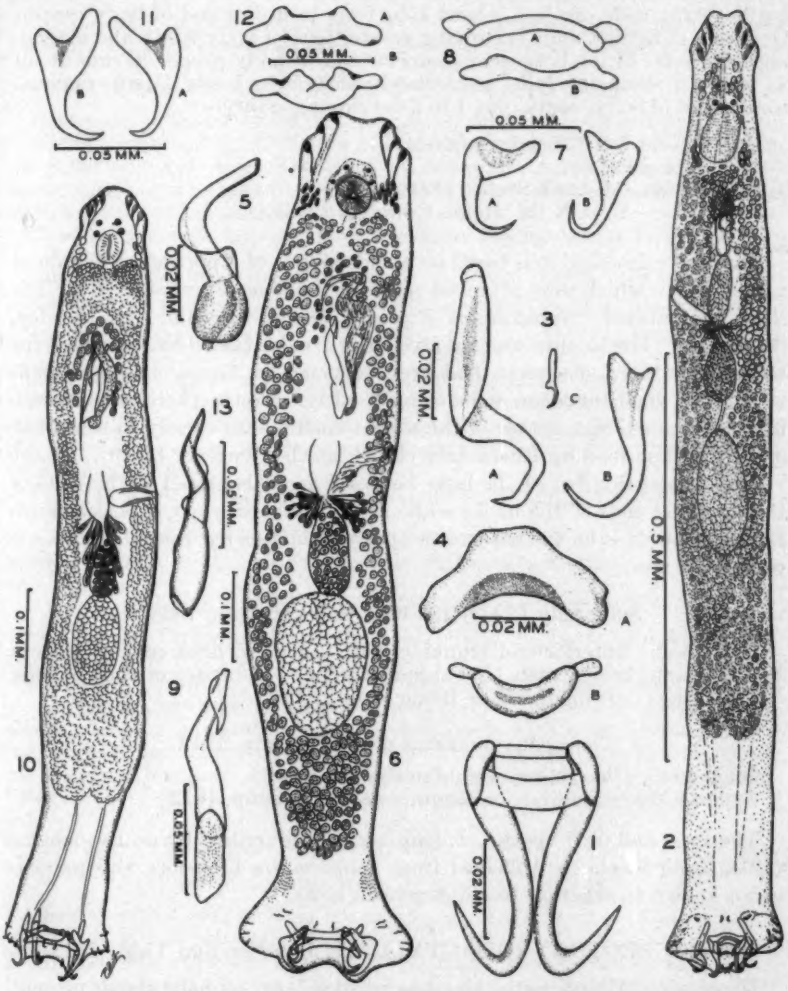


Fig. 1.—*Gyrodactylus gurleyi*. Large haptoral hooks, dorsal view. Figs. 2–5.—*Ancyrocephalus teuthis*. 2, Complete worm, ventral view; 3, haptoral hooks (A—hook of dorsal pair, B—hook of ventral pair, C—marginal hooklet); 4, haptoral bars (A—dorsal bar, B—ventral bar); 5, cirrus. Figs. 6–9.—*Ancyrocephalus lactophrys*. 6, Complete worm, ventral view; 7, large haptoral hooks (A—hook of ventral pair, B—hook of dorsal pair); 8, haptoral bars (A—ventral bar, B—dorsal bar; drawn to same scale as Fig. 7); 9, cirrus. Figs. 10–13.—*Ancyrocephalus similis*. 10, Complete worm, ventral view; 11, haptoral hooks (A—hook of ventral pair, B—hook of dorsal pair); 12, haptoral bars (A—ventral bar, B—dorsal bar); 13, cirrus.

branches simple. Genital apertures not observed. Testis oval, 20 to 38μ long by 20 to 25μ wide, median, about 155μ from posterior end of body proper. Ovary an indistinct mass occupying greater part of body width and extending from level of testis to near posterior end of body proper. Ovum about 23 to 27μ in diameter, lying immediately anterior to testis. Uterus in equatorial third of body, containing 1 to 2 developing embryos.

Host.—Gold fish ("Japanese fan-tail").
Location.—Fins.
Distribution.—United States (Texas).
Specimens.—U. S. N. M. Helm. Coll. No. 39584.

The above description is based on a slide mount of a portion of the fin of a gold fish to which were attached several specimens of gyrodactylids. The slide was labeled "*Gyrodactylus elegans*—Japanese fan-tail—Dr. Gurley, Sept. 1891." The locality was not given, but Dr. A. Hassall has informed the writer that these specimens had been collected in Texas. The specimens were not in good condition and a complete description is, therefore, impossible. The general appearance of the worms corresponds closely to that of *G. medius* as described by Kathariner (1895) and by Wegener (1910), but the ventral supporting bar of the large haptoral hooks is placed at the level of the proximal ends of the hooks while in *G. medius* this bar is placed much farther back. It is on the basis of the position of this bar that the species is considered new.

Subfamily ISANCISTRINAE Fuhrmann, 1928

Diagnosis.—Anterior end truncate, with 1 pair of head organs. Haptor without large hooks, with 15 marginal hooklets. Parasites of cephalopods.
Type genus.—*Isancistrum* de Beauchamp, 1912.

Genus ISANCISTRUM de Beauchamp, 1912

Diagnosis.—Characters of subfamily.
Type species.—*Isancistrum loliginis* de Beauchamp, 1912.

The type and only species, *I. loliginis*, was described by de Beauchamp (1912) from specimens collected from *Loligo media* Linneaus; this parasite is not known to occur on North American hosts.

Family PROTOGYRODACTYLIDAE Johnston and Tiegs, 1922

Diagnosis.—Minute forms, about as broad as long; cephalic glands present, opening to exterior through well developed head organs. Haptor well developed, with 2 pairs of large hooks and with a number of relatively large marginal hooklets. Intestine branched, the two limbs may or may not unite posteriorly. Eyes present. Testis and ovary unbranched. Cirrus simple, cuticular, tube-like. Vitelline glands lateral, arranged in 2 groups, one preovarial and the other postovarial; transverse vitelline ducts connected by median longitudinal duct; posterior transverse vitelline duct with definite connection with intestinal limbs. Vagina absent. Parasites of fresh-water fishes.
Type genus.—*Protogyrodactylus* Johnston and Tiegs, 1922.

KEY TO GENERA OF PROTOGYRODACTYLIDAE

Posterior vitelline system double.....*Trivitellina* Johnston and Tiegs
Posterior vitelline system single.....*Protogyrodactylus* Johnston and Tiegs

Genus PROTOGYRODACTYLUS Johnston and Tiegs, 1922

Diagnosis.—Haptor broad, not sharply set off from body proper, strongly "padded," provided with 2 pairs of large hooks and 12 marginal hooklets, the latter relatively large. Intestinal branches not united posteriorly. Vitellaria consisting of a preovarial and a postovarial system; posterior transverse vitelline duct communicating with intestine.

Type species.—*Protogyrodactylus quadratus* Johnston and Tiegs, 1922.

The type and only species of this genus occurs on the gills of *Therapon carbo* Ogilby and McCulloch and *T. hilli* Castelnau in Australia.

Genus TRIVITELLINA Johnston and Tiegs, 1922

Diagnosis.—Haptor sharply set off from body, not strongly "padded," provided with 2 pairs of large hooks and 12 marginal hooklets as in *Protogyrodactylus*. Intestinal branches united posteriorly. Vitellaria consisting of 1 preovarial system and 2 postovarial systems, one of the latter connected with the intestine.

Type species.—*Trivitellina subrotunda* Johnston and Tiegs, 1922.

The type and only species of this genus is known only from Australia where it occurs on the gills of *Therapon fuliginosus* Macleay.

Family DACTYLOGYRIDAE Bychowsky, 1933

Synonyms.—Gyrodactylidae Cobbold, 1877, in part; Amphibdellidae Carus, 1885.

Diagnosis.—Anterior end with 2 or more pairs of head organs; cephalic glands lateral, or distributed throughout median, preoral area (Bothitrematinae). Haptor moderately to well developed, with or without accessory structures or squamodiscs, and with 1 or 2 pairs of large hooks and usually 14 marginal hooklets. Ovary globular, sometimes curved, pretesticular. Vitellaria well developed. Vagina present or absent. Oviparous. Parasites of fishes.

Type genus.—*Dactylogyrus* Diesing, 1850.

KEY TO SUBFAMILIES OF DACTYLOGYRIDAE

1. Haptor with 1 pair of large hooks.....2
   Haptor with 2 pairs of large hooks.....3
2. Haptor with a circle of heavily cuticularized, tubular structures.....
   .....Bothitrematinae Price
   Haptor without circle of tubular structures. Dactylogyrinae Bychowsky
3. Haptor with a pair (dorsal and ventral) of accessory structures or squamodiscs.....Diplectaninae Monticelli
   Haptor without accessory structures or squamodiscs.....
   ..... Tetraonchinae Monticelli

Subfamily DACTYLOGYRINAE Bychowsky, 1933

Synonyms.—Gyrodactylinae Monticelli, 1892, in part.

Diagnosis.—Haptor moderately developed, without squamodiscs, with 1

pair of large hooks supported by 1 or 2 heavily cuticularized clamp-like bars, and with 14 marginal hooklets. Intestine double, branches usually, if not always, united posteriorly. Eyes present. Testis and ovary rounded, the latter always pretesticular. Vagina present, with or without cuticular supporting structures.

Type genus.—*Dactylogyrus* Diesing, 1850.

Genus Dactylogyrus Diesing, 1850

Diagnosis.—Characters of subfamily.

Type species.—*Dactylogyrus auriculatus* (Nordmann, 1832) Diesing, 1850.

The genus *Dactylogyrus* contains the following species: *D. aequans* Wagener, 1857; *D. affinis* Bychowsky, 1933; *D. alatus* Linstow, 1878; *D. amphibothrium* Wagener, 1857; *D. anchoratus* (Dujardin, 1845); *D. auriculatus* (Nordmann, 1832); *D. bini* Kikuchi, 1929; *D. chranilowi* Bychowsky, 1933; *D. cornu* Linstow, 1878; *D. crucifer* Wagener, 1857; *D. cryptomeres* Bychowsky, 1934; *D. kulwieći* (Bychowsky, 1931); *D. cyprini* Buschkiel, 1930; *D. difformis* Wagener, 1857; *D. dujardinianus* (Diesing, 1850); *D. extensus* Mueller and Van Cleave, 1932; *D. falcatus* (Wedl, 1857); *D. fallax* (Wagener, 1857); *D. formosus* Kulwieć, 1927; *D. fraternus* Wegener, 1910; *D. frisii* Bychowsky, 1933; *D. gracilis* Wedl, 1861; *D. haplogonus* Bychowsky, 1933; *D. intermedius* Wegener, 1910; *D. inversus* Goto and Kikuchi, 1917; *D. macracanthus* Wegener, 1910; *D. malleus* Linstow, 1877; *D. megastoma* Wagener, 1857; *D. minor*, Wagener, 1857; *D. minutus* Kulwieć, 1927; *D. mollis* (Wedl, 1857); *D. nybelini* Markevich, 1933; *D. parvus*, Wegener, 1910; *D. propinquus* Bychowsky, 1931; *D. puntii* Buschkiel, 1930; *D. siluri* Wagener, 1857; *D. similis* Wegener, 1910; *D. simplicimalleata* Bychowsky, 1934; *D. sphyrna* Linstow, 1878; *D. tenuis* Wedl, 1857; *D. tuba* Linstow, 1878; *D. uncinatus* Wagener, 1857; *D. vastator* Nybelin 1924 (syn. *D. crassus* Kulwieć, 1927); *D. wegeneri* Kulwieć, 1927; *D. wunderi* Bychowsky, 1931; and *D. zandti* Bychowsky, 1933. Only two of these species, *D. extensus* and *D. anchoratus*, are known to occur in North America, the former occurring on the gills of *Cyprinus carpio* and the latter on *Carassius auratus*.

Subfamily TETRAONCHINAE Monticelli, 1903

Diagnosis.—Body devoid of scales or spines. Haptor without squamodiscs, with 2 pairs of large hooks and (?) 2 to 16 marginal hooklets. Intestine single or double. Eyes present or absent. Testis usually without lobes. Ovary without lobes. Vagina present or absent.

Type genus.—*Tetraonchus* Diesing, 1858.

KEY TO GENERA OF TETRAONCHINAE[3]

1. One pair of head organs ..... *Diplectanotrema* Johnston and Tiegs
   More than 1 pair of head organs 2

[3] The recent genera by Mueller (1936, 1937) may not all be valid; they have been included in this key pending further study. *Dactylodiscus* Olsson is omitted from the key as it is too imperfectly known; it may belong to this subfamily and is appended as a genus inquirenda.

2. Intestine single ..... *Tetraonchus* Diesing
   Intestine double 3
3. Intestine uniting posteriorly 4
   Intestine not uniting posteriorly 15
4. Eyes absent ..... *Tetrancistrum* Goto and Kikuchi
   Eyes present 5
5. Vitellaria not extending into posterior third of body 6
   Vitellaria extending into posterior third of body 7
6. Vagina present ..... *Daitreosoma* Johnston and Tiegs
   Vagina absent ..... *Empleurosoma* Johnston and Tiegs
7. Dorsal and ventral haptoral hooks dissimilar .... *Aristocleidus* Mueller
   Dorsal and ventral haptoral hooks similar 8
8. Haptor disc-like; haptoral bars articulate ..... *Actinocleidus* Mueller
   Haptor wedge-shaped; haptoral bars non-articulate 9
9. Large haptoral hooks unequal, ventrals about one-half as large as dorsals ..... *Haplocleidus* Mueller
   Large haptoral hooks equal or nearly so 10
10. Large hooks each with flattened blade arising near angle ..... *Pterocleidus* Mueller
    Large hooks without blades 11
11. Marginal hooklets relatively large, 6 pairs arranged around anterior edge of haptor, their points projecting forward ..... *Onchocleidus* Mueller
    Marginal hooklets relatively small, mostly projecting backward ... 12
12. Cirrus long and slender, thrown into wide spiral; without movable accessory piece ..... *Leptocleidus* Mueller
    Cirrus usually short, with movable accessory piece 13
13. Vagina absent ..... *Urocleidus* Mueller
    Vagina present 14
14. Vagina dextral ..... *Tetracleidus* Mueller
    Vagina sinistral ..... *Cleidodiscus* Mueller
15. Eyes present 16
    Eyes absent 18
16. Vagina absent ..... *Anchylodiscus* Johnston and Tiegs
    Vagina present 17
17. Vagina aperture median; haptor with 3 bars ..... *Murraytrema*, n. g.
    Vaginal aperture lateral; haptor with 2 bars ... *Ancyrocephalus* Creplin
18. Haptor without bars ..... *Amphibdella* Chatin
    Haptor with 1 or 2 bars 19
19. Haptor with 1 bar ..... *Amphibdelloides*, n. g.
    Haptor with 2 bars ..... *Haliotrema* Johnston and Tiegs

Genus TETRAONCHUS Diesing, 1858

Synonym.—*Monocoelium* Wegener, 1910.

Diagnosis.—Cephalic glands opening to exterior through several pairs of head organs. Haptor more or less distinctly set off from body proper, with 2 pairs of large hooks supported by a single large transverse cuticular bar; 16 marginal hooklets. Intestine single, without diverticula. Eyes present. Testes and ovary in equatorial zone. Vagina absent.

Type species.—*Tetraonchus monenteron* (Wagener, 1857) Diesing, 1858.

The genus *Tetraonchus* contains two species, *T. monenteron* (Wagener, 1857), reported by Van Cleave and Mueller (1934) from *Esox lucius* from

Oneida Lake, New York, and *T. alaskensis* Price, reported by the present writer (1937) from the gills of *Salmo mykiss* Walbaum, *Salvelinus malma spectabilis* (Giard) and *Oncorhynchus kisutch* Walbaum from Alaska.

Genus Ancyrocephalus Creplin, 1839

Synonyms.—*Diplectanum* Auct.; *Tetraonchus* Diesing, 1858, in part.

Diagnosis.—Head organs usually 3 pairs. Haptor indistinctly set off from body proper. Large hooks supported by 2 cuticular bars; 14 marginal hooklets. Intestinal branches not united posteriorly. Eyes present. Testis and ovary equatorial or postequatorial. Vitellaria usually extending into posterior third of body. Vagina present.

Type species.—*Ancyrocephalus paradoxus* Creplin, 1839.

The following species belong to the genus *Ancyrocephalus: A. atherinae* Price, 1934; *A. bassensis* Hughes, 1928; *A. lactophrys* (MacCallum, 1915); *A. manilensis* Tubangui, 1931; *A. paradoxus* Creplin, 1839; *A. similis*, n. sp.; *A. teuthis* (MacCallum, 1915); *A. tylosuri* (MacCallum, 1917); *A. vanbenedenii* (Parona and Perugia, 1890); and *A. vesiculosus* Murray, 1931. Of these species, *A. atherinae*, *A. lactophrys*, *A. similis*, *A. teuthis*, and *A. tylosuri* occur on North American fishes; descriptions of the forms from this continent except *A. atherinae* from *Atherina araea* Jordan and Gilbert, which was described by the present writer (1934), are given below.

Ancyrocephalus teuthis (MacCallum, 1915)

Johnston and Tiegs, 1922 Figs. 2–5

Synonym.—*Diplectanum teuthis* McCallum, 1915.

Description.—Body slender, 1.1 to 1.2 mm long by 96 to 114μ wide, sides parallel; anterior end slightly notched and somewhat narrower than remainder of body; cephalic glands present, in 4 groups, 1 group on each side of base of pharynx and 1 group on each side of median line anterior to oral aperture, opening to exterior through 3 pairs of head organs. Haptor 133μ wide, not set off from body proper, with 2 pairs of large hooks supported by 2 cuticular bars and with 14 marginal hooklets; 2 small crescentic bodies also present in median line, lying side by side at level of roots of dorsal hooks. Large hooks unequal and dissimilar; those of dorsal pair sickle-shaped, 57 to 58μ long, apparently with single, handle-like root and with angular blade; hooks of ventral pair simple 42, to 45μ long, with slightly biramous roots; dorsal supporting bar somewhat yoke-shaped, about 45μ long, ventral bar yoke-shaped, 43 to 49μ long; marginal hooklets 15μ long. Oral aperture ventral, at level of posterior pair of head organs; pharynx oval, 57μ long by 45μ wide; intestine not discernible. Eyes present, 2 pairs, anterior to pharynx. Genital aperture median, about 250μ from anterior end of body. Cirrus tubular, curved, about 57μ long, with delicate spiral ala. Testis oval, 133μ long by 57μ wide, equatorial. Ovary oval, median, pretesticular. Vitellaria extending from level of base of pharynx to about one-fourth of body length from posterior end. Vagina present, opening on right side of body about 325 to 245μ from anterior end. Ootype elongate, its base surrounded by unicellular glands. No eggs observed.

Host.—*Acanthurus hepatus* (Linnaeus).

Location.—Gills.

Distribution.—United States (New York Aquarium).
Specimens.—U. S. N. M. Helm. Coll. Nos. 35689 (cotypes), 35690 and 35691.

Three slides containing several specimens and representing collections made by Dr. G. A. MacCallum on May 22, 1914; March 17, 1915; and November 24, 1915, respectively, were available for study. The specimens were fairly well preserved and stained, but some structures figured by MacCallum (1915), such as the esophageal glands, seminal vesicle and seminal receptacle, could not be made out.

The most distinguishing feature of the species is the structure of the dorsal hooks of the haptor; these have relatively long, apparently uniramous roots and peculiarly curved blades.

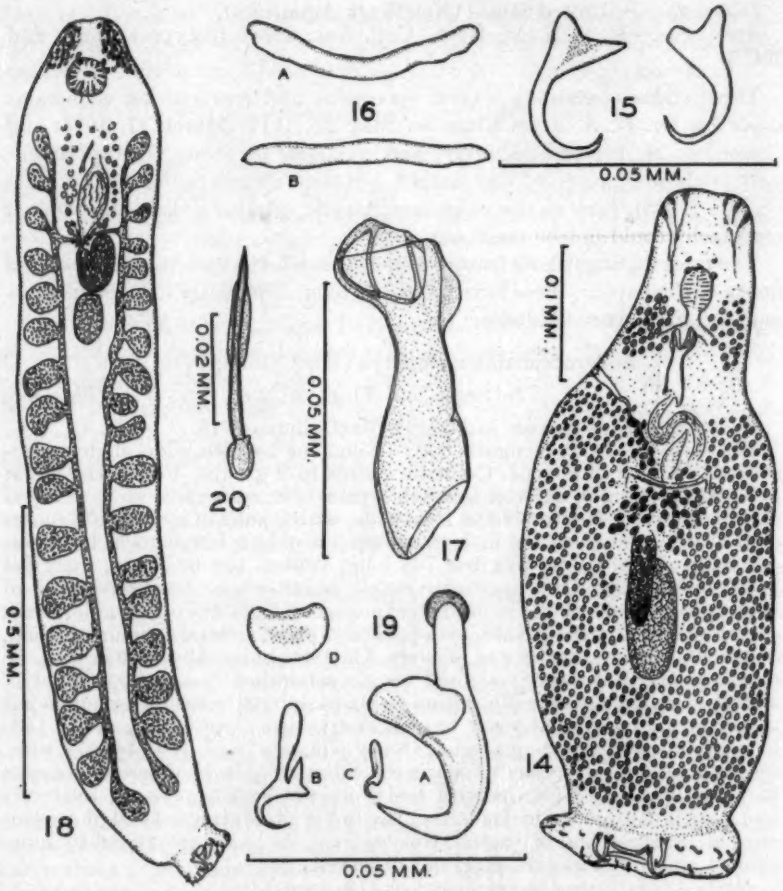
Ancyrocephalus lactophrys (MacCallum, 1915)
Johnston and Tiegs, 1922 Figs. 6–9

Synonym.—*Diplectanum lactophrys* MacCallum, 1915.
Description.—Body elongate, 650 to 950μ long by 150μ wide, slightly constricted at level of ootype. Cephalic glands in 2 groups, 1 on each side of pharynx, opening to exterior through 3 pairs of head organs; no esophageal glands observed. Haptor 170 to 190μ wide, with 2 pairs of large hooks separated by cuticular bars, and with 14 marginal hooklets. Large hooks biramous 49μ long; dorsal supporting bar 76μ long, ventral bar 68μ long; marginal hooklets 15μ long. Oral aperture ventral, about 80μ from anterior end of body; pharynx about 38μ in diameter; intestinal tract not observable. Brain antero-dorsal to oral aperture; eyes present, 2 pairs. Genital aperture median, about 200μ from anterior end of body. Cirrus tubular, about 105μ long, no accessory piece observed; seminal vesicle somewhat S-shaped, to right of cirrus; vas deferens extending from testis to seminal vesicle, passing to left of cirrus and curving anterior to genital aperture. Testis oval, about 150μ long by 95μ wide, postequatorial. Ovary elongate oval, 100μ by 57μ wide, immediately pretesticular. Vitellaria extending from level of base of pharynx to near junction of haptor with body proper. Vagina present, relatively large, with distinct cuticular lining, the lining presenting a twisted appearance at proximal end of vagina. Ootype oval, its base surrounded by long-necked unicellular glands. Eggs not observed.
Host.—*Acanthostracion quadricornis* (Linnaeus).
Location.—Gills.
Distribution.—United States (New York Aquarium).
Specimens.—U. S. N. M. Helm. Coll. No. 35692 (cotypes).

Several specimens of this species were collected by Dr. G. A. MacCallum, February 19, 1915, from the gills of *Lactophrys tricornis* (=*Acanthostracion quadricornis*). The above description is based on these specimens.

Ancyrocephalus similis, n. sp. Figs. 10–13

Description.—Body elongate, 850 to 936μ long by 100 to 115μ wide, lateral margins almost parallel for entire length. Cephalic glands on each side of pharynx, opening to exterior through 3 pairs of head organs. Haptor not set off from body proper, with 2 pairs of large hooks supported by 2 cuticular bars, and with (?) 14 marginal hooklets. Large hooks 57 to 60μ



Figs. 14–17.—*Ancyrocephalus tylosuri*. 14, Complete worm, ventral view; 15, haptoral hooks; 16, haptoral bars (A—dorsal bar, B—ventral bar; drawn to same scale as Fig. 15); 17, cirrus. Figs. 18–20.—*Diplectanotrema balistes*. 18, Complete worm, ventral view; 19, haptoral hooks and bar (A—hook of ventral pair, B—hook of dorsal pair, C—marginal hooklet, D—bar); 20, cirrus.

long, roots biramous; dorsal supporting bar 42 to 57μ long, ventral bar 57 to 65μ long; marginal hooklets about 10μ long. Oral aperture ventral, about 40μ from anterior end of body; pharynx 40μ long by 30μ wide; intestinal tract not observed. Eyes present, 2 pairs, anterior to oral aperture. Genital aperture median, about 200μ from anterior end of body. Cirrus 76 to 95μ long, similar in shape to that of *A. lactophrys*. Testis oval, 75μ long by 55μ wide, postequatorial. Ovary elongate, median, pretesticular. Vitellaria as in *A. lactophrys*. Vagina short, without twisted cuticular lining as in *A. lactophrys*. No eggs observed.

Hosts.—*Priacanthus arenatus* Cuv. and Valenc. and *P. cruentatus* (Lacépède).

Location.—Gills.

Distribution.—United States (New York Aquarium).

Specimens.—U. S. N. M. Helm. Coll. Nos. 35693 (type and paratypes) and 35694.

This species is based on specimens collected by Dr. G. A. MacCallum. Two slides containing a number of specimens from each of the above-mentioned hosts were available; the specimens from *Priacanthus arenatus* had been collected June 20, 1915, and those from *P. cruentatus* on May 30, 1915.

Ancyrocephalus similis resembles *A. lactophrys* so closely that on casual examination the two forms appear to be identical. However, there are very significant differences in the morphology of the large hooks, supporting bars and cirri of the two species, which appear sufficient to warrant recognizing them as distinct.

Ancyrocephalus tylosuri (MacCallum, 1917)
Johnston and Tiegs, 1922 Figs. 14–17

Synonym.—*Diplectanum tylosuri* MacCallum, 1917.

Description.—Body somewhat elliptical, 510 to 645μ long by 170 to 210μ wide, anterior end more or less abruptly constricted. Cephalic glands numerous, on each side of pharynx, opening to exterior through 3 pairs of head organs. Haptor disc-like, about 150μ wide, more or less sharply set off from body proper, with 2 pairs of large hooks supported by 2 cuticular bars, and with 14 marginal hooklets. Large hooks similar in shape, 23μ long, with slightly biramous roots; ventral bar slightly sinuous, about 38μ long; dorsal bar curved, about 38μ long; marginal hooklets about 12μ long. Oral aperture ventral, 50 to 55μ from anterior end of body; pharynx oval, 27μ long by 19μ wide; intestinal tract not observed. Eyes present, 2 pairs, anterior to pharynx. Genital aperture median, about 100μ from anterior end; cirrus 57μ long, tubular, expanded distally, without accessory piece; seminal vesicle S-shaped. Testis oval, about 75μ long by 40μ wide, postequatorial. Ovary linguiform, 75μ long by 20μ wide, partly overlapping testis. Vitellaria occupying greater part of body from level of base of cirrus to posterior end of body proper. Vagina present, cuticular, somewhat trumpet-shaped, opening at body margin immediately in front of anterior limit of left vitellarium. Ootype elongate, its base surrounded by numerous, relatively large, unicellular glands. Eggs not observed.

Host.—*Strongylura marina* (Walbaum).

Location.—Gills.

Distribution.—United States (New York Aquarium).

Specimens.—U. S. N. M. Helm. Coll. No. 35695 (cotypes).

This species was described by MacCallum (1917) from specimens collected May 4, 1916 from a silver gar at the New York Aquarium; this redescription is based on the original specimens. All of the specimens had been stained and mounted and were not in good condition, consequently very little could be added to the original description. *A. tylosuri* may be easily distinguished from all other species of the genus by the position of the vaginal aperture and by the structure of the cirrus.

Ancyrocephalus spp.

Undetermined species of *Ancyrocephalus* have been reported from freshwater fishes in this country by Hess (1928, 1930) and by Van Cleave and Mueller (1934). In view of the fact that the genus *Ancyrocephalus, s. str.*, is composed of species from marine fishes, it appears safe to conclude that the forms reported by the above writers do not belong to that genus.

Genus HALIOTREMA Johnston and Tiegs, 1922

Diagnosis.—Body slightly constricted in equatorial region; 4 to 5 pairs of head organs. Haptor distinctly set off from body proper, with 2 pairs of large hooks supported by a pair of clamp-like bars, and with 14 marginal hooklets. Intestinal limbs not united posteriorly. Eyes absent. Testis and ovary in posterior third of mid-region of body. Cirrus large, complex. Vagina present, with heavily cuticularized lumen.

Type species.—*Haliotrema australe* Johnston and Tiegs, 1922.

This genus contains two species, *H. australe* Johnston and Tiegs from *Upeneus signatus* Gunther and *H. japonense* Yumaguti, from *Pseudupeneus chrysopleuron* (Tem. and Schl.), neither of which occurs in this country. So far as the writer has been able to ascertain this genus does not differ from *Ancyrocephalus* in any important character; the absence of eyes, if they are actually absent, seems to be the most important difference. Both Johnston and Tiegs (1922) and Yamaguti (1934) call attention to 2 pairs of gland cells in the vicinity of the oral cavity, but the arrangement of these cells suggests the possibility of unpigmented eyes having been mistaken for gland cells; however, until specimens of representatives of the genus are available for study this point cannot be settled and for the time being *Haliotrema* may be regarded as valid.

Genus DIPLECTANOTREMA Johnston and Tiegs, 1922

Diagnosis.—Body more or less uniform in width, 1 pair of head organs. Haptor cup-like, not distinctly set off from body proper, armed with 2 pairs of large hooks, the hooks of the 2 pairs markedly unequal and dissimilar, and with 14 marginal hooklets. Eyes present. Ovary and testis in anterior third of body; cirrus simple. Vitellaria consisting of very large discrete follicles arranged in linear series along sides of body, extending to near posterior end of body proper. Vagina apparently absent.

Type species.—*Diplectanotrema balistes* (MacCallum, 1915) new comb.

This genus was proposed as a subgenus of *Ancyrocephalus* by Johnston and Tiegs (1922) to contain *Diplectanum plurovitellum* MacCallum, 1916. This subgenus is regarded here as a distinct genus with *D. balistes* (MacCallum) as type, since, as will be shown later in this paper, MacCullum's *Diplectanum plurovitellum* and his *D. balistes* are identical, the latter having priority.

Diplectanotrema differs from *Ancyrocephalus* in having a single pair of head organs, in the marked dissimilarity of the large hooks of the haptor, and in the character of the vitellaria which are composed of large discrete

follicles arranged in linear series along each side of the body instead of small irregularly arranged follicles as in *Ancyrocephalus*.

Diplectanotrema balistes (MacCallum, 1915), n. comb. Figs. 18–20

Synonyms.—*Diplectanum balistes* MacCallum, 1915; *Ancyrocephalus balistes* (MacCallum, 1915) Johnston and Tiegs, 1922; *Diplectanum plurovitellum* MacCallum, 1916; *Ancyrocephalus* (*Diplectanotrema*) *plurovitellum* (MacCallum, 1916) Johnston and Tiegs, 1922.

Description.—Body elongate, sides almost parallel, 850μ to 1.4 mm long by 150 to 220μ wide; cephalic glands present, prepharyngeal, opening to exterior through 1 pair of head organs. Haptor cup-like, 95μ wide, not distinctly set off from body proper, with 2 pairs of large hooks supported by a single heavily cuticularized bar, and with 14 marginal hooklets; large hooks of ventral pair relative large, 42μ long, with biramous roots; hooks of dorsal pair taenioid, 20μ long; supporting bar more or less rectangular, 10μ by 15μ; marginal hooklets about 10μ long. Oral aperture ventral, median, about 100μ from anterior end; pharynx globular, 57 to 75μ in diameter; esophagus very short; intestine not traceable in available specimens. Brain antero-dorsal to pharynx; eyes present, 2 pairs. Genital aperture median, about 200μ from anterior end of body. Cirrus slender, tubular, 40μ long; accessory piece apparently simple. Testis oval, 95μ long by 57μ wide, about one-third of body length from anterior end. Ovary somewhat U-shaped, about 95μ long by 68μ wide. Vitellaria lateral, consisting of large discrete follicles arranged in linear series, each series connected by means of a longitudinal vitelline duct. Vagina apparently absent. Ootype relatively large, its posterior end surrounded by unicellular glands; large gland cells also present in median field on each side of ootype. Egg oval, 75μ long by 45μ wide.

Hosts.—*Balistes capriscus* Gmelin, *Acanthurus* (*Teuthis*) *hepatus* (Linnaeus) and *Anisotremus virginicus* (Linnaeus).

Location.—Gills.

Distribution.—United States (New York Aquarium).

Specimens.—U. S. N. M. Helm. Coll. Nos. 35696 (cotypes), 35697 (cotypes of *Diplectanum plurovitellum*) and 35698.

Diplectanotrema balistes was originally described as *Diplectanum balistes* by MacCallum (1915) from specimens collected January 13, 1913, from the gills of a trigger fish, *Balistes carolinensis* (=*B. capriscus*), at the New York Aquarium. The next year MacCallum (1916) described under the name of *Diplectanum plurovitellum* a species from the gills of *Teuthis hepatus* and *Anisotremus virginicus;* specimens from the former host were collected November 27, 1915, and those from the latter on March 5, 1916, as a slide bearing that date was found in his collection. The specimens from the two last mentioned hosts appear to be the same as those collected from *Balistes carolinensis*, since a careful comparison of these specimens revealed no essential differences. The specimens were not in good condition as they had apparently been fixed under pressure of a cover slip and somewhat distorted; due apparently to improper fixation, the specimens stained unevenly, and it seems that the difference in staining was responsible for the failure of MacCallum to recognize that he was dealing with a single species instead of two species. Some structures described and figured by MacCallum could

not be made out. The intestine which in his *D. balistes* is figured as consisting of 2 limbs, and which in his description of *D. pleurovitellum* is described as seeming "to join into a single tube posterior to the testis" could not be made out in any of the specimens; no vagina could be made out, although it is possible that a vagina may be present but so collapsed by pressure that it could not be located.

(to be continued)

MALACOLOGY.—*Two new land shells from Cuba.*[1] PAUL BARTSCH, U. S. National Museum.

Cuba is the malacologists' paradise, for nowhere else do we find such a differentiation and concentration of land shells as is found on the "Pearl of the Antilles." On this account the Island has attracted to it naturalists of fame from the early days of malacology. The scholarly Poey, as well as men like Pfeiffer, Otto, Gundlach, Sagra, Wright and Arango, have all left their impress upon this science. However, it seems as if the mantle of all these explorers and naturalists, who have furthered our science, had fallen upon Cuba's genial scientist and scholar, Dr. Carlos de la Torre, whose researches in the malacological field have fine-tooth-combed the Island and brought to our ken treasures far excelling the greatest expectation that the earlier explorers might have visioned.

Working over a huge collection of Cuban shells has brought to light two of the most exquisite forms known to science, and I take great pleasure in dedicating both of them to my friend, Don Carlos.

Chondropometes (Chondropometes) torrei, n. sp. Fig. 2

Shell rather large, turbinate, thin, semi-translucent, openly umbilicated. Nuclear whorls translucent, pale yellow, the succeeding turns orange buff with varicial streaks of deeper orange. Peristome flame colored. Nuclear whorls about 2, in perfect conformity in their coiling with the postnuclear turns. The first thin, translucent, appearing granulose under high magnification; the last marked by feeble, somewhat retractively slanting, closely spaced, incremental lines. The postnuclear whorls inflated, well rounded, marked by very regular, retractively slanting sublamellar axial riblets which are a little less wide than the spaces that separate them. These riblets extend over the periphery into the umbilicus of the last turn, remaining of about the same strength throughout. In addition to these, there are narrow orange streaks at more or less regular intervals, which are occasioned by the approximation of two or more riblets. These are a little lighter than the rest of the shell. The spiral sculpture consists of almost obsolete threads which are narrower than the spaces that separate them and which render the riblets slightly wavy and under high magnification feebly serrulate. They are best developed on the anterior half of the whorls. The spiral threads are obsolete

[1] Published by permission of the Secretary of the Smithsonian Institution. Received February 1, 1937.

on the base but become strengthened within the umbilicus on the parietal wall where they are heavier. Suture well impressed; periphery inflated, well rounded. Base inflated, well rounded. Aperture subcircular with a slight angulation at the posterior angle. The peristome is broadly expanded and reflected, about half as wide as that of *Chondropometes* (*Chondropometes*) *latilabre* d'Orbigny. It is appressed to the preceding turn at the posterior angle. Behind the peristome the last whorl is solute for about one-fifteenth of a turn. Operculum thin, multispiral, horny with a fine granulose, callus-like deposit, which is heaviest on the inner margin and thins out outwardly, vanishing a little beyond the middle of the turn. This deposit is laid down in a more or less corrugated pattern. The typical race of this species, for at least nine are known at this time which will be described later, was collected by Dr. de la Torre on Mogote Canalete, Abra de Bejarano, at the western end of the Sierra San Andrés, Pinar del Rio Province, Cuba. It is the most magnificent of all the members of the genus known today.

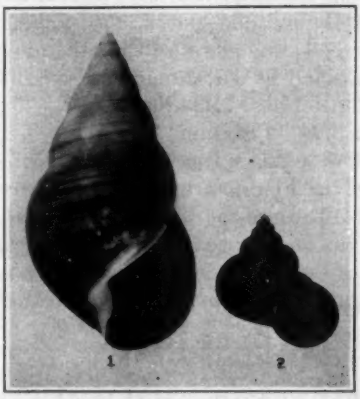


Fig. 1.—*Liguus crenatus caroli*, n. subsp. Fig. 2.—*Chondropometes* (*Chondropometes*) *torrei*, n. sp. Seven-eighths natural size.

The type, U.S.N.M. Cat. No. 428794, a perfect specimen, has 6.0 whorls and measures: Length 23.0 mm; greater diameter 22.3 mm; lesser diameter 15.9 mm.

This species stands midway in distribution between *Chondropometes* (*Chondropometes*) *vignalense* and *Chondropometes* (*Chondropometes*) *latilabre*, and its characters are midway between these two extremes. These are constant for all the races that we have seen, and we shall therefore assign subspecic rank to them in a subsequent paper.

Liguus crenatus caroli, n. subsp. Fig. 1

Shell large, turritid, covered with a thin periostracum. The early whorls ivory colored, which is soon succeeded by faint lemon yellow, which becomes intensified and eventually gives way to orange axial streaks and finally to an orange outer lip in young shells. The whorls in addition to this are marked by spiral bands and lines of olive green, which are a little paler on the base

than on the spire, but on the last part of the base become much intensified and more or less confluent. The aperture is characteristically that of *Liguus*, the outer lip being thin, the pillar being slightly truncated anteriorly to form a somewhat tooth-like projection, the parietal callus extending down over the columella. The nucleus consists of about 3 whorls, which are in perfect alignment with the postnuclear spire. They are marked by fine, rather distantly spaced, spiral striations, which disappear on the early turn of the postnuclear spire.

This subspecies comes from Turiguano Island off the north coast of Camaguey Province. The type, U.S.N.M. Cat. No. 428810, has 8 whorls and measures: Length 56.9 mm; greater diameter 30.3 mm; lesser diameter 27.2 mm; length of aperture 26.0 mm; diameter of aperture 17.8 mm.

We collected this subspecies on the expedition which I made to Cuba under the Walter Rathbone Bacon Traveling Scholarship of the Smithsonian Institution in 1928. The specimens collected at that time were rather small, none having attained the full dimensions listed for the type. The red color in these young individuals was more brilliant than it is in the type, which was subsequently collected by Dr. de la Torre or some of his friends and donated by him to the National Museum.

U.S.N.M. Cat. No. 384712 contains 12 paratypes.

It is quite possible that this subspecies is responsible for the orange element that we find in the Floridian hybrid *Liguus* complex. This does not seem at all improbable because the Island of Turiguano is in the middle of the north coast of Cuba and hurricanes could easily carry young specimens across that distance, or they might in a hibernating state be tucked away in a knothole of some log and might then have drifted to Floridian shores.

PROCEEDINGS OF THE ACADEMY AND AFFILIATED SOCIETIES

THE ACADEMY

39TH ANNUAL MEETING

The 39th Annual Meeting of the Washington Academy of Sciences was held in the Assembly Hall of the Cosmos Club, January 21, 1937, with 32 members present. President MEINZER called the meeting to order at 9:30 P.M.

The minutes of the 38th Annual Meeting were read and approved. The Corresponding Secretary, NATHAN R. SMITH, submitted the following report on the membership and activities of the Academy:

Membership: During 1936, 13 were elected to resident and 7 to non-resident active membership. Of these, 12 qualified for resident and 3 for non-resident members, a total of 15 new members. Four were elected in recognition of their work in Chemistry; 4, in Forestry; 2, in Anthropology; 2, in Physics; and 1 each in Horticulture, Paleontology and Zoology. There were 7 resignations, 1.3% (2 resident and 5 non-resident), and 5 deaths. The net gain in membership was, therefore, 3.

The members of the Academy stood in respect as the Secretary read the names of those lost by death.

B. L. ROBINSON, Cambridge, Massachusetts, July, 1935.
A. N. CAUDELL, Washington, D. C., March 1, 1936.
W. H. WILMER, Washington, D. C., March 12, 1936.
A. F. FOERSTE, Washington, D. C., April 23, 1936.
J. A. NIEUWLAND, Notre Dame, Indiana, June 11, 1936.

On January 1, 1937, the membership consisted of 14 honorary members, 3 patrons and 524 active members, one of which was a life member. Of the active members, 387 were classed as resident and 137 as non-resident. Since the By-Laws limit the number of active members to 400 resident and 200 non-resident, there were, therefore, 13 vacancies in the resident and 67 non-resident vacancies.

The Board of Managers held four meetings with an average attendance of 17. The following amendment to the By-Laws was passed by the Board and ratified by the membership by an almost unanimous vote:

"Article 1, Section 2. Active members who have been in good standing for the previous ten years and who have been retired because of age or disability, shall be relieved of further payment of dues but shall have all the privileges of active membership."

Article 1, Section 1, to read, "The number of active members, *excepting those who have retired as provided for in Section 2*, shall not exceed six hundred, etc. . . ."

Since there are several active members who have been retired in the past few years, the amendment will create more vacancies than has usually been the case. This is especially true of resident members.

The Recording Secretary presented the following report:

The 39th year of the Academy began with the 269th meeting and ended with the 275th meeting. All seven meetings were held in the Assembly Hall of the Cosmos Club.

The 269th meeting was held jointly with the Chemical Society of Washington on January 30, 1936. About 175 persons were present. FREDERIC BARRY, Professor of the History of Science, Columbia University, delivered an address upon *The new Aristotle.*

The 270th meeting was held jointly with the Philosophical Society of Washington on February 20, 1936. Dr. W. J. HUMPHREYS discussed *Some episodes along the meteorological highway.*

The 271st meeting was held on March 19, 1936, with 212 persons present. The four reel Leeuwenhoek Tercentenary Film was presented by MORRIS C. LEIKIND of the Institute of the History of Medicine of The Johns Hopkins University, and the two reel film on The Mammalian Egg: Its Ovulation, Fertilization and Development, was presented by EVERETTE I. EVANS, Bureau of Dairy Industry, Department of Agriculture.

The 272nd meeting was held jointly with the Botanical Society of Washington on April 16, 1936, with about 200 persons present. Prof. E. D. MERRILL, Administrator of Botanical Collections of Harvard University, gave an illustrated address on *Plants and civilizations.*

The 273rd meeting was held jointly with the Geological Society of Washington on November 19, 1936, with about 95 persons present. Mr. GEORGE H. ASHLEY, State Geologist of Pennsylvania, gave an address on *The emergence of ideas as illustrated from geology.*

The 274th meeting was held on Thursday, December 17, 1936, with about 85 persons present. Dr. HENRY B. WARD, Professor Emeritus of Zoology of the University of Illinois, gave an illustrated address on *Salmon psychology*.

The 275th meeting of the Academy was held January 21, 1937, with 75 persons present. Vice-President SILSBEE introduced Retiring President O. E. MEINZER who addressed the Academy upon the subject, *Our water supply*.

The report of the Treasurer, H. G. AVERS, was read by HOWARD S. RAPPLEYE:

CASH RECEIPTS AND DISBURSEMENTS

Receipts			
From Back Dues		$ 135.00	
From Dues for 1936		2,385.00	
From Dues for 1937		35.00	
From Subscriptions for 1936		787.00	
From Subscriptions for 1937		264.70	
From Subscriptions for 1938		6.00	
From Sales of Journals		52.58	
From Payments for Reprints		293.82	
From Sales of 1935 Directory		5.40	
From Interest on Deposits		28.21	
From Interest on Investments		1,181.50	
From Sale of Bond of Va. Rys.		1,099.25	
Total receipts			$6,273.76
Cash Balance January 1, 1936			2,368.77
To be accounted for			$8,642.53
Disbursements			
For Secretary's Office, 1935		$ 7.00	
For Secretary's Office, 1936		272.80	
For Treasurer's Office, 1935		2.75	
For Treasurer's Office, 1936		187.80	
For Journal Office, 1935		35.73	
For Journal Office, 1936		43.34	
For Journal Printing, 1935		27.38	
For Journal Printing, 1936		2,281.62	
For Journal Reprints, 1935		95.57	
For Journal Reprints, 1936		437.17	
For Illustrations, 1936		267.36	
For Illustrations, 1937		20.98	
For Meetings Committee, 1935		20.00	
For Meetings Committee, 1936		303.87	
For Affiliated Societies Committee		2.60	
Bank Debit Memos, as follows:			
Dues	$0.35		
Subscriptions	.23		
Reprints	.35	.93	
Total Disbursements			$4,006.90
Cash Balance December 31, 1936			4,635.63
Total			$8,642.53

NOTE: Of the above expenditures, $188.43 was paid chargeable to 1935 and $20.98 was paid chargeable to 1937.

The Auditing Committee, HOWARD S. RAPPLEYE and GEORGE TUNELL, reported:

"The Treasurer's records of receipts and expenditures as shown in his account books and included in his report have been examined and found correct. All vouchers have been examined and found to be correct and properly approved. The balance sheets submitted by the bank and the securities

listed in the Treasurer's report have been examined. The statement of the assets of the Academy was found correct. No coupons not yet due were missing from any of the securities bearing coupons. The records of the Treasurer's Office have been carefully and systematically kept, thus greatly facilitating the work of the auditing committee."

The Board of Editors, F. G. BRICKWEDDE, R.W. BROWN, and E.H. TOOLE, submitted the following report covering the publication of Volume 26 of the Journal for the year 1936:

"There were 76 original papers. Forty-four of them were by members of the Academy and 32 were communicated. Original papers were illustrated by 73 line cuts and 17 half-tones. Excess cuts illustrating several papers were paid for by the respective authors. Space in the volume was distributed among the different sciences, as follows:

	Pages
10 papers on Physics, including Astronomy, Geophysics and Crystallography	116.3
3 papers on Chemistry	17.5
2 papers on Medicine including Physiology	19.8
10 papers in Paleontology including Paleobotany	49.0
7 papers on Entomology	32.9
17 papers on Botany	84.0
26 papers on Zoology	152.7
1 paper on General Science	30.0

Proceedings of the Academy and affiliated societies occupied 34.5 pages, as follows:

The Academy	6.0
Botanical Society	1.4
Geological Society	12.0
Philosophical Society	15.1

Obituaries occupied 2.6 pages.

The Journal is relatively speaking up-to-date with manuscripts submitted to it."

The tellers, F. G. TRYON, K. S. MARKLEY and L. V. JUDSON, reported the election of the following officers: President, CHARLES THOM; Non-resident Vice Presidents, THOMAS BARBOUR, Cambridge, Massachusetts, and P. W. BRIDGMAN, Cambridge, Massachusetts; Corresponding Secretary, NATHAN R. SMITH; Recording Secretary, OSCAR S. ADAMS; Treasurer; H. G. AVERS; Board of Managers, F. G. BRICKWEDDE and J. F. COUCH.

The Corresponding Secretary read the list of nominations for vice-president submitted by the affiliated societies as follows:

Philosophical Society of Washington, FRANK WENNER
Anthropological Society of Washington, F. H. H. ROBERTS, JR.
Biological Society of Washington, H. C. FULLER
Washington Section, American Chemical Society, J. H. HIBBEN
Entomological Society of Washington, C. F. W. MUESEBECK
National Geographic Society, A. WETMORE
Geological Society of Washington, W. T. SCHALLER
Medical Society of the District of Columbia, H. C. MACATEE
Columbia Historical Society, ALLEN C. CLARK
Botanical Society of Washington, JOHN A. STEVENSON
Archaeological Society of Washington, ALES HRDLICKA

Washington Section, Society of American Foresters, S. B. DETWILER
Washington Society of Engineers, PAUL C. WHITNEY
Washington Section, American Institute of Electrical Engineers, H. L. CURTIS
Washington Section, American Society of Mechanical Engineers, H. L. WHITTEMORE
Helminthological Society of Washington, EMMETT W. PRICE
Washington Branch, Society of American Bacteriologists, H. W. SCHOENING
Washington Post, Society of American Military Engineers, C. H. BIRDSEYE
Washington Section, Institute of Radio Engineers, J. H. DELLINGER

By vote of the Academy, the Recording Secretary was instructed to cast one vote for the list as read and the vice-presidents were declared elected.

President MEINZER appointed Past Presidents McCOY and TUCKERMAN to escort President-elect THOM to the chair. President THOM took over the gavel and addressed the Academy briefly.

Adjournment followed at 10:15.

CHARLES THOM, *Recording Secretary*